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Environmental Assessment of a Coal Preheater

York Research Corp.
Stamford, CT

Prepared for

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16. ABSTRACT The report gives results of a program to determine particulate and organic emissions from a Cerchar coal preheater at Jones and Laughlin Steel Corp.'s Aliquippa Works. Scrubber removal efficiency for particulate, measured by EPA Method 5, ranged from 86 to 93%. Emissions at the scrubber outlet ranged from 95 to 468 g/M-ton of coal and increased with coal feed rate. Lower preheat temperature improved scrubber efficiency. At the scrubber outlet, chloroform-soluble organic emissions ranged from 11 to 414 g/M-ton coal; benzene-soluble organic emissions ranged from 186 to 397 g/M-ton coal. Total POM emissions ranged from 4.7 to 23.4 g/M-ton coal. Scrubber efficiency for removal of organics was lower than for particulate removal and increased with increasing coal feed rate. Preheater outlet temperature increased both inlet and outlet concentrations, but did not affect scrubber efficiency. GC/MS analysis showed extreme variability in POM specie concentrations. POM species exceeding their Discharge Multimedia Environmental Goal (DMEG) values in the scrubber outlet were: phenanthrene, benz(a)anthracene, benzo(a)pyrene, 7,12-dimethylbenz(a)anthracene, and 3-methyl cholanthrene.

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Environmental Assessment of a Coal Preheater

by

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1.0 Summary

York Research Corporation (YRC) contracted by the Environmental Protection Agency to undertake a research study which would evaluate emissions associated with a coal preheater system. Testing was conducted in July and August of 1978 on a system installed at the Jones and Laughlin (J&L) Steel Corporation's Aliquippa Works, Aliquippa, Pennsylvania.

The primary objectives of the study were to:

- Characterize particulate and organic emissions from the coal preheater system
- Identify and quantify polycyclic organic materials (POM) which may be present in the emissions
- Relate emission characteristics to the processing conditions of the preheater system.

The testing program centered around the north unit scrubber of the preheater system. Gas stream inlet and outlet testing was as follows:

- Samples for chloroform and non-chloroform soluble particulate were taken using a standard EPA-5 sampling train
- Samples for POM analysis were taken using a POM train which is essentially an EPA-5 train with an adsorber located downstream of the filter.
- Samples for benzene soluble organics (BSO) were taken using a POM train

The following grab samples were also obtained:

- Scrubber gas inlet and outlet - analyzed for benzene and total hydrocarbon content
- Scrubber water inlet and outlet -analyzed for POM's

- Preheater inlet and outlet coal samples - analyzed for ash, volatiles, carbon, hydrogen, sulfur, and moisture

The results of an emission study conducted on this same preheater system, done by Betz Environmental Engineers, Inc. for (B.E.E.) for J&L Steel Corp., have been incorporated into this report in order to expand the data base. B.E.E. testing was done in March and April of 1977; however, the physical and operational aspects appear to have been the same as during the YRC test period.

1.1 Particulate Emissions

A summary of EPA-5 particulate emissions is given in Table 1-1. These results are based on a total of 40 tests (36 B.E.E./4 YRC) and show the effect of process changes. Generally, inlet particulate concentration is unaffected by preheater outlet temperature and is lowest for a coal feed rate of 95 M-ton/hr. Outlet concentration tends to increase with increasing preheater outlet temperature, especially at higher coal feed rates, and with higher feed rates. Scrubber efficiency decreases with increasing feed rate and also decreases with outlet temperatures at higher feed rates.

PA-DER method particulate concentration shows the same trend (see Figures 10-1, 10-2, and 10-3).

POM train particulate concentration at the scrubber inlet was highly variable and shows no substantial trend with process conditions. Outlet concentration increases with both coal feed rate and outlet temperature; consequently, scrubber efficiency decreases. Inlet concentrations ranged from 4.398 to 21.26 mg/Nm^3, outlet concentrations from .287 to 1.764 mg/Nm^3, and scrubber efficiency from 98.9 to 83%.

BSO train particulate concentration is summarized in Table 1-2. No effect of process conditions can be discerned on the basis of only three tests.

1.2 Organic Emissions

Table 1-3 presents a summary of chloroform soluble emissions based on the 36 tests conducted by B.E.E. and 4 by YRC. Below a coal feed rate of 95 M-ton/hr, scrubber inlet concentrations increase primarily with increasing preheater outlet temperature. Above this point, inlet concentrations also increase strongly with increasing coal feed rate. Outlet concentrations increase with both process conditions but the effect of preheater outlet temperature appears to be dominant. Scrubber efficiency ranges between 41 and 65% and is higher at the lower temperature.

Benzene soluble emissions are given in Table 1-4. Process characterization is not possible on the basis of three tests; however, scrubber efficiency is lower than for the chloroform solubles.

An EPA Level 1 organic analysis was run on 2 stack samples, 2 water samples, and 2 blanks. Aliphatic hydrocarbons, fused aromatic hydrocarbons, phenols, and esters were the major components in the stack air samples. Aliphatic hydrocarbons, carbazoles, and phenols were the major components in the water samples.

1.2.1 Polycyclic Organic Material, (POM)

Twenty-two stack air samples were analyzed by GC/MS for 25 POM species. Only 22 species were found. Concentrations of individual species were highly variable and were not consistent from test to test. This could be due to natural variations in the coal processed or in the coke oven gas as produced or burned. Among the compounds analyzed, the most prevalent species found were napthalene, anthracene, and phenanthrene. Lesser amounts of fluorene, pyrene, fluoranthene, benzanthracene, chrysene, and benzopyrenes were also found.

Gravimetric analysis showed that total POM concentration was

3 to 14% of the aromatic fraction which was 23 to 67% of the total organic sample extract. Total POM emissions are summarized in Table 8-4. Total POM concentrations at the scrubber outlet were strongly dependent on coal feed rate, increasing with higher feed rates. The effect of preheater outlet temperature was much less. Scrubber inlet concentrations increased with both preheater outlet temperature and coal feed rate.

Total POM scrubber efficiency increased with higher coal feed rates and ranged from 17.8 to 71.6%.

Six water samples were analyzed by GC/MS for POM's. Only the lightest molecular weight species were found. Total POM concentration was significantly lower than was expected in the scrubber outlet water. It is possible that the high concentration of particulate matter (which a high percentage of carbon) in the outlet samples adsorbed a large portion of POM material.

In order to estimate the toxicity level of the POM emissions, these emissions were compared to their corresponding Discharge Multimedia Environmental Goal (DMEG) levels. This comparison showed that, for most of the air samples, the following species exceed their DMEG levels. Phenanthrene, Benz(a)anthracene, Benzo(a)pyrene, 7,12-dimethylbenz(a)anthracene, and 3-methyl cholanthrene. None of the POM species found in the water samples exceeded their DMEG levels.

1.2.2 Benzene and Total Hydrocarbons

Eight inlet and outlet stack gas grab samples were analyzed for benzene and total hydrocarbon concentrations. Significantly higher concentrations were found in the outlet samples. Six water samples were also analyzed for benzene and none was found. It is possible that any light hydrocarbons in the water samples volitilized before the samples were analyzed. The evidence, however, indicates that the benzene and light hydrocarbons were introduced by the water stream. The scrubber water system, as it existed during testing, was open to possible sources of

accidental contamination. Condensate from the charging bin vent condensor was also led to the scrubber pumping tank. This is another possible source of light hydrocarbons.

2.0 Conclusions

Scrubber removal efficiency for particulate ranged from 86 to 93%. Emissions at the scrubber outlet ranged from 95 to 468 g/M-ton of coal. This is based on combined EPA-5 method results obtained by York Research and Betz Environmental Engineers.

Process conditions had a significant effect on particulate emissions. In general, outlet loadings increased with coal feed rate which decreased scrubber efficiency. However, a significant improvement in scrubber efficiency was obtained at the lower preheater outlet temperature (271°C).

Particulate results obtained from POM and BSO tests follow the same trends noted for EPA-5 particulate.

At the scrubber outlet chloroform soluble organic emissions ranged from 11 to 414 g/M-ton coal and benzene soluble organic emissions from 186 to 397 g/M-ton coal. Total POM emissions ranged from 4.7 to 23.4 g/M-ton. Scrubber efficiency for removal of organics was lower than for particulate removal and increased with increasing coal feed rate. Preheater outlet temperature increased both inlet and outlet concentrations, but did not affect scrubber efficiency.

GC/MS analysis showed extreme variability in POM specie concentraions. The following POM species exceeded their Discharge Multimedia Environmental Goal (DMEG) levels: phenanthrene, benz(a)anthracene, benzo(a)pyrene, 7,12-dimethylbenz(a)anthracene, and 3-methyl cholanthrene.

3.0 Recommendations

3.1 Program Design

A unified systems approach should be taken to any future studies; i.e., engineering, testing, and analytical personnel should be involved in all phases of the program.

Design of an appropriate test program depends on a clear understanding of program objectives, process characteristics and conditions, and analytical requirements and objectives. Thus, the input of engineering and analytical expertise is required at the very start so that sampling techniques and methodology can be taylored in advance to the specific situation. Program objectives, in turn must be established using a knowledge of analytical and sampling problems which may arise.

3.2 Test Program

In light of the rapid process fluctuations and frequent interruptions experienced, future sampling procedures must be designed to accommodate these characteristics of the coal preheater system. Strict simultaneity between inlet and outlet samples must be observed. Short sampling periods are necessary to establish the range of process variation while very long periods are required to establish typical emission rates. In addition, simultaneous sampling of the water stream is required in order to provide a mass balance and a check on test results, especially for organic emissions. Analysis of all samples must be done as quickly as possible in order to avoid loss of volatiles and particulate matter in the water samples must be desorbed of organic material.

To determine the source of particulate and organic emission variation, testing of the coal and coke oven gas is also required.

This report provides information on a coal preheater system operating under a limited number of conditions; i.e., coal feed rate and preheater outlet temprature. Total characterisation of coal preheater emissions would also require the study of the effect of:

- o various liquid to gas ratios in the scrubber
- o recycle water quality
- o different coal mixes and sizing
- o various scrubber pressure drops

3.3 Sampling Trains

The high particulate loading found in the scrubber inlet gas stream required that many filter changes be made during sampling. One modification to the standard test train which would reduce this problem would be to install a cyclone at the probe tip. This would reduce the size of particulate reaching the filter.

A velocity meter/recorder should be used in place of the usual manometer in order to improve sampling accuracy with changing stack gas velocity.

TABLE 1-1

SUMMARY OF PARTICULATE EMISSIONS

(EPA-5 METHOD)

Process Conditions *	Inlet			Outlet			η
	mg/Nm^3	Kg/Hr	g/M-Ton	mg/Nm^3	Kg/Hr	g/M-Ton	%
82/271	18586	395.4	4822	1334	20.0	244	93
95/271	15366	295.6	3111	1347	21.3	224	91
109/271	15528	314.2	2882	1791	28.5	353	88
76/278	--	--	--	953	7.3	95	--
82/288	18267	361.4	4407	1357	21.9	266	93
95/288	12981	257.9	2714	1814	30.2	318	86
109/288	15116	288.7	2649	2020	51.0	468	87

* (M-Tons Coal/Hr)/(Preheater Outlet Temp., ^{o}C)

TABLE 1-2

SUMMARY OF PARTICULATE EMISSIONS

(BSO-TRAIN)

Process Conditions *	Inlet			Outlet			η
	mg/Nm^3	Kg/Hr	g/M-Ton	mg/Nm^3	Kg/Hr	g/M-Ton	%
82/271	10362.6	291	3547	982.6	18.7	228	91
109/271	8266.2	308	2827	3262.7	95.3	875	61
55/288	17285	337	6133	1664.8	25.5	463	90

* (M-Tons Coal/Hr)/(Preheater Outlet Temp., ^{o}C)

TABLE 1-3

SUMMARY OF CHLOROFORM SOLUBLE ORGANIC EMISSIONS

(EPA-5 METHOD)

Process Conditions	Inlet			Outlet			η
	mg/Nm^3	Kg/Hr	g/M-Ton	mg/Nm^3	Kg/Hr	g/H-Ton	%
82/271	1235	26.3	321	492	7.4	90	60
95/271	1144	22.0	232	675	10.7	113	41
109/271	3146	63.7	584	1086	17.3	159	65
76/278	--	--	--	110	0.8	11	--
82/288	1398	27.7	338	789	12.7	155	44
95/288	1688	33.5	352	1000	16.6	175	41
109/288	3347	63.9	586	1787	45.1	414	47

TABLE 1-4

SUMMARY OF BENZENE SOLUBLE ORGANIC EMISSIONS

(PA-DER METHOD)

Process Conditions *	Inlet			Outlet			η
	mg/Nm^3	Kg/Hr	g/M-Ton	mg/Nm^3	Kg/Hr	g/M-Ton	%
82/271	1157	35.5	435	783	14.9	186	32
109/271	2741	106.3	970	1930	55.4	534	30
55/288	1279	25.0	458	1344	21.8	397	--

* (M-Tons Coal/Hr/(Preheater Outlet Temp., ^{o}C)

4.0 Introduction

The concept of using a closed charging system to reduce emissions during coking processes along with a coal preheater to improve coke throughput and economy is an attractive idea. Typical practice in the steel industry has been to charge coke ovens through openings in the oven tops with wet coal. This practice results in a large amount of pollutants. The installation of a closed charging system offers the potential of greatly reducing the quantity of emissions and confines them to a single source.

In an effort to better understnad the character of emissions associated with such a system, the EPA sponsored York Research Corp to undertake a research study. Testing was done in July and August, 1978,around the north unit scrubber of a coal preheater system installed at Jones and Laughlin Steel Corp.'s Aliquippa steel mill in Aliquippa, Pennsylvania.

Special attention was given to the detection and analysis of polycyclic organic materials (POM's). A modified EPA-5 particulate train was used during the sampling to be sure any POM's would be captured.

Testing was conducted at several levels of preheater operation so that emissions could be related to system operation.

5.0 Process Description

Modern integrated steel mills incorporate all the facilities needed to produce finished steel products from basic raw materials. Part of this process is the reduction of iron ore to metallic iron which is done in blast furnaces. Carbon, which is provided as coke, has been found to be the best reduction agent. A charge of iron ore, coke, and limestone is put in the top of a blast furnace. Hot blast air entering near the bottom of the furnace passes through the charge and forms a gas with the coke which reduces the oxides in the ore to metallic iron. Impurities react with the limestone to form slag.

The coke necessary to this process is produced by heating coal at 900 to 1100°C for a period of 10 to 20 hours to drive off all volatile materials.

5.1 Coking Process

Essentially all the coke in this country is produced using the by-product recovery process. Coal is heated in the absence of oxygen in closed ovens. The volatiles driven off are recovered and partially offset the cost of making coke.

The ovens are typically 18m long, 6.5m high but only 50cm wide and alternate, in a structure called a battery which may contain 80 to 120 ovens, with heating chambers in which coke oven (and/or blast furnace) gas is burned. The heating chambers provide the heat required for distillation by conduction through the oven walls. The volatiles given off during the coking process include tars, light oils, vaporized hydrocarbons, napthalene, and coke oven gas.

At the end of the coking period, doors at both sides of the oven are opened. A ramming device on one side pushes the hot coke into a quench car located on the other side of the oven. The quench car takes the coke to a quench tower where the coke is cooled with water sprays. The coke is then stored for use in the blast furnaces. The oven is meanwhile given a new charge of coal. Each oven in the battery is at a different stage of the coking process at any given moment so that production is continuous for the battery.

The typical uncontrolled oven charging process gives off 60% of the atmospheric emissions associated with this coking process. Wet coal, blended and weighed, is loaded into the hoppers of a larry car which moves along the top of the battery. The larry car is positioned over an oven requiring a charge and the coal is dumped through open charging ports at the top of the oven. Hot gases in the oven are displaced and pollutants such as hydrocarbons, graphite, tars, char, and coal dust are emitted. The charging ports of the oven are then closed and the distallation process begins.

There are several modifications of this system which are aimed at reducing emissions. They include aspiration systems, which attempt to increase the draft in the oven; larry mounted scrubbers; and closed charging systems.

5.2 Charging System

The emissions test program reported herein was conducted at coking facilities which used a Coalteck Pipeline charging system with a Cerchar coal preheater. A schematic drawing of this system is given in Figure 5-1. This is a closed system which substantially improves coke quality and has the potential for reducing emissions.

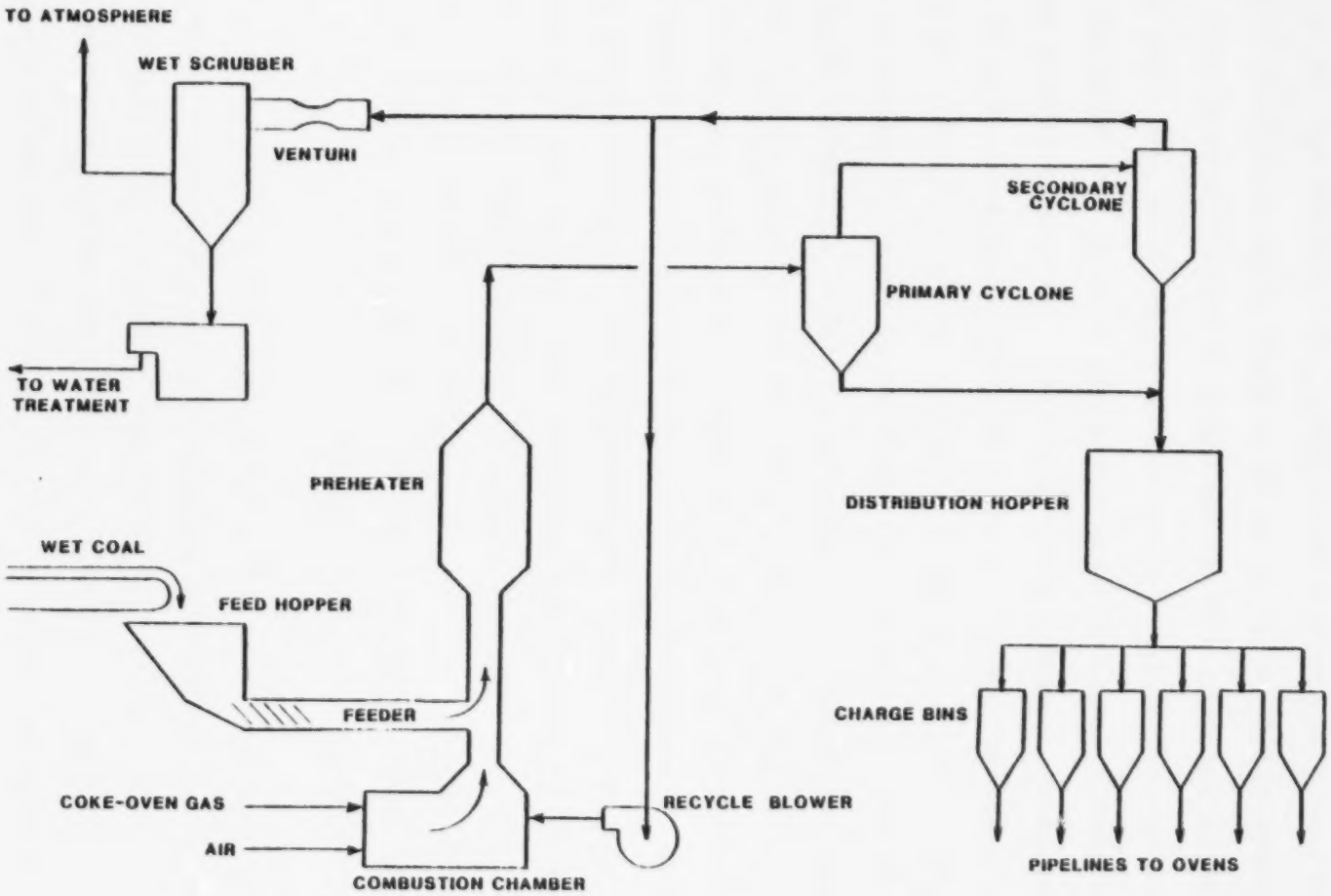


FIGURE 1

CERCHAR COAL PREHEATER WITH COALTEK PIPELINE CHARGING SYSTEM

In this system, wet coal is withdrawn by screw conveyor from existing coal storage facilities. It is sized and fed to the Cerchar preheater by a variable speed screw conveyor. The wet coal is fed into a flash drying entrainment section where it comes into contact with a stream of hot oxygen-free gas. The gas carries the partly dried, entrained coal up through the preheater. In the combustion chamber, low-sulfur coke oven gas is burned nearly stoichiometrically with air for complete combustion with low residual oxygen. The hot gases leaving the combustion chamber are a mixture of freshly burned gas and recycled products of combustion. The mixed gases leave the combustion chamber at a temperature of 385 to 650°C, and pass through the venturi section of the preheater. The wet coal is pushed into this high velocity gas stream by the feed screw. Temperature at the upper end of the flash drying section is in the 260°C range. The preheated coal passes overhead and is recovered in primary and secondary conventional cyclone separators. Hot coal from the bottom of the cyclones feeds to a distribution bin. From the distribution bin, coal is distributed to one of six charging bins. Coal is discharged from the charging bins through a pipeline system which feeds the oven being charged.

Gas from the outlet of the secondary cyclones is split into two streams. Gas volumes equivalent to the combustion gases and moisture driven off the coal go to a venturi scrubber for cleaning before being exhausted to the atmosphere. The remaining gas volume is boosted in pressure by means of a recycle fan and then returned to the combustion chamber where it is used to temper and add to the flow of the combustion gases passing up through the preheater. Automatic controls adjust the pressure differential across the secondary

cyclones to maintain the desired flow of gases through the preheater.

5.3 Scrubber Water System

Of particular interest in this report is the scrubber water treatment system. A schematic diagram of the system is shown in Figure 5-2. It should be noted that this was the system used at the time of testing and that major modifications have since been made.

Scrubber effluent is piped to a splitter tank where heavy particulate matter is settled out. The scrubber water, less the heavy particulate, flows to a flotation cell where buoyant materials are skimmed out and removed. The clarified water flows to the venturi scrubber pumping tank from which it is pumped back to the scrubber.

Preheated coal is moved from the distribution and charging bins by pressurizing these bins with steam. When coal is discharged from a bin, the coal discharge valve opens and the coal is forced out of the bin and along the appropriate pipeline by the steam pressure in the bin. The bins are then depressurized by venting to the distribution bin vent condenser tank. A small quantity of clarifier scrubber water by-passes the scrubber and is used in the condenser. The condensate is drained to the splitter tank.

The vented steam from each of the six charging bins is condensed in a single charging bin vent condenser tank. Make-up water is used to condense this steam. The condensate from this tank flows directly into the scrubber pumping tank.

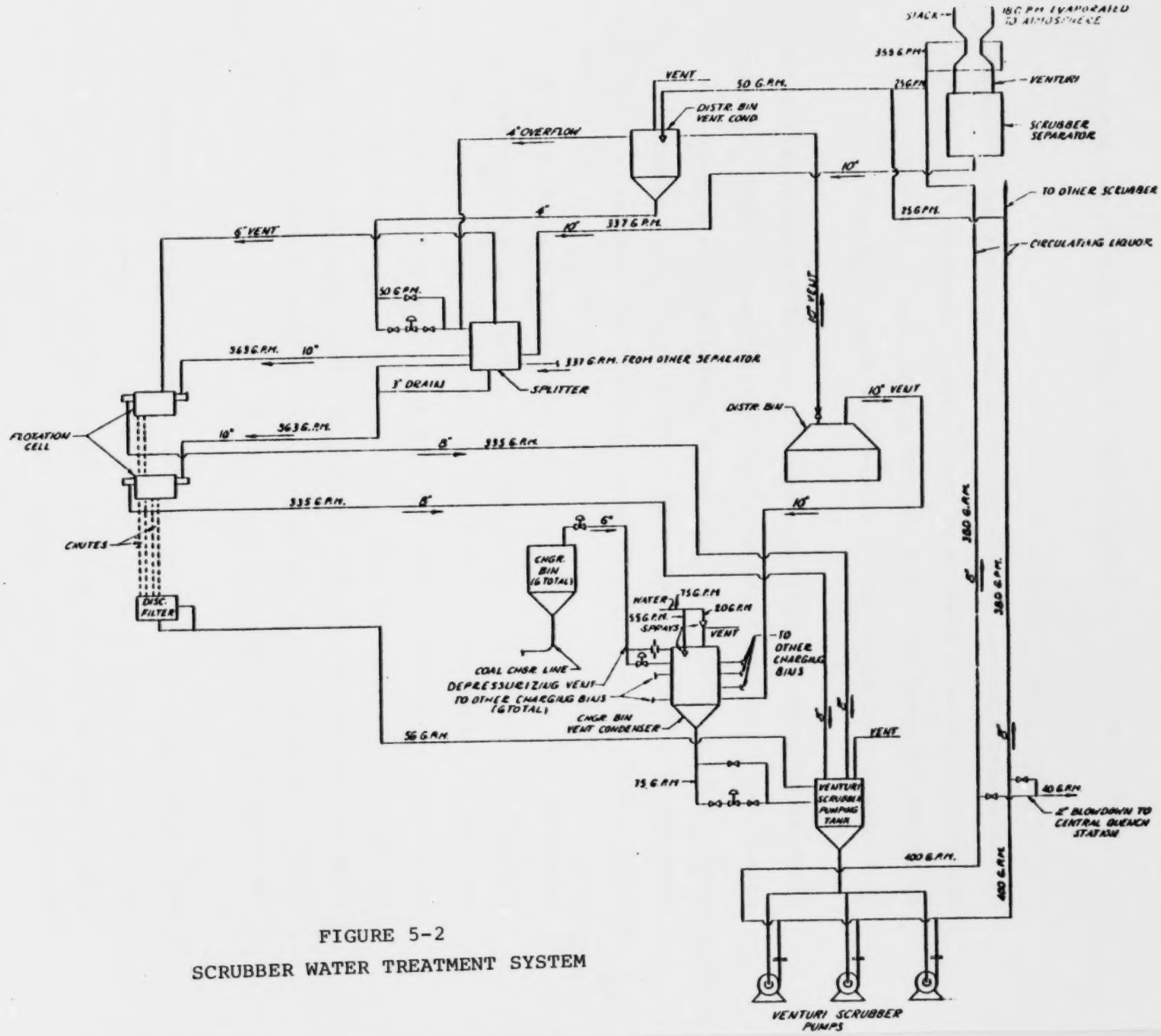


FIGURE 5-2

SCRUBBER WATER TREATMENT SYSTEM

6.0 TEST PROCEDURES

6.1 Test Program

The test program was conducted around the north scrubber unit of the Jones and Laughlin Steel Corporation's Aliquippa coal preheater in July and August of 1978. A summary of the testing accomplished is given in Table 6-1.

For the gas stream sampling; velocity, temperature, gas analysis, and other parameters required for particulate and polycyclic organic material (POM) sampling were recorded and isokinetic sampling maintained as specified by the following E.P.A. Methods:

- Method #1 - Sampling and velocity traversed for stationary sources.
- Method #2 - Determination of stack gas velocity and volumetric flow rate (type S pitot tube).
- Method #3 - Gas analysis for CO_2, O_2, CO and dry molecular weight using an Orsat unit.
- Method #4 - Determination of moisture content in stack gas, derived from actual sampling train.
- Method #5 - Determination of particulate in the inlet and outlet of the scrubber.

In addition to the above, gas stream sampling was also performed for the following parameters by the methods noted:

- Polycyclic organic materials (POM) in the inlet and

outlet of the scrubber with particulate weight reported. (POM Method).

- o Benzene soluable organics (BSO) in the inlet and outlet of the scrubber with particulate weight reported. (POM Method).
- o Benzene and total hydrocarbon (THC) concentrations in the inlet and outlet of the scrubber. (Grab flask method).
- o Chloroform soluble organics (CSO) in the inlet and outlet of this scrubber. (Using EPA-5 particulate samples).
- o Sulfur content in the impinger catches of the inlet and outlet sampling trains. (Using POM test samples).

Scrubber inlet and outlet water was sampled by the grab flask method to determine POM levels.

Coal samples were collected for each test period. These samples were analyzed for ash, volatiles, hydrogen, and sulfur for fractions larger and smaller than 100 mesh. In addition, 2 coal samples were analyzed for trace metals.

TABLE 6-1

SUMMARY OF YRC TESTING

PARAMETER	NO. OF TESTS	SAMPLING METHOD	ANALYTICAL METHOD	SAMPLING LOCATION (Across Scrubber Unless Noted)
POM	22	POM Train	IR, LRMS, Combined GC/MS	10 Inlet 12 Outlet
Level 1 Organics	6	(2) Gas (POM Train) (2) Water (Grab Flask) (2) Blank	EPA-1 Organics	Gas: POM Test #2 (Inlet & Outlet)
Particulate and CSO	4	EPA-5 Train	EPA-5 for Particulate PA-DER for CSO	1 Inlet 3 Outlet
BSO	6	POM Train	EPA-5 Modified	3 Inlet 3 Outlet
Sulfur in Impinger Catches	2	POM Train	Grav. Method w/ignition of residue	POM Test #1 (Inlet & Outlet)
Benzene & THC	15	Grab Flask	GC	
POM in Scrubber Water	6	Grab Flask	Combined GC/MS	3 Inlet 3 Outlet
Coal Analysis	21	Grab Sample	All: ASTM for Volatiles, Ash, C, H_2, S, Size (2): Spark Source for trace metals	9 Inlet 10 Outlet (Sampling done across coal preheater

6.2 Sampling Point Determinations

EPA Method 1 was used to determine the location of a representative sampling point within both the 45" I.D. Inlet duct and the 44" I.D. Outlet Duct. The Inlet Duct sampling location was downstream of the recycle loop branch. The outlet sampling location was the scrubber stack. Each test run was conducted until a minimum of one (1) cu. meter (at meter conditions) was obtained.

The Inlet scrubber water samples were taken at the blowdown Inlet line on Level 3. The Outlet samples were taken from the return line upstream of the connection with the return line from the south scrubber unit. This was at Level 7 just upstream of the splitter tank.

6.3 Gas Velocity

The gas velocity was determined in accordance with guidelines outlined in EPA Method 2 (Determination of Stack Gas Velocity and Volumetric Flow Rate).

A precalibrated type S pitot tube and thermocouple attached to the sampling probe were used to measure the velocity pressure on an inclined manometer. (see Figure 6-1)

6.4 Gas Composition

The gas composition was determined in accordance with guidelines outlined in EPA Method 3 (Gas Analysis for Carbon Dioxide, Oxygen, Excess Air and Dry Molecular Weight).

A sample line was attached to the sampling probe and sample drawn by a vacuum pump into an evacuated Tedlar bag. The contents of the bag were then analyzed for O_2, CO_2 and CO with an Orsat Analyser. (see Figure 6-2)

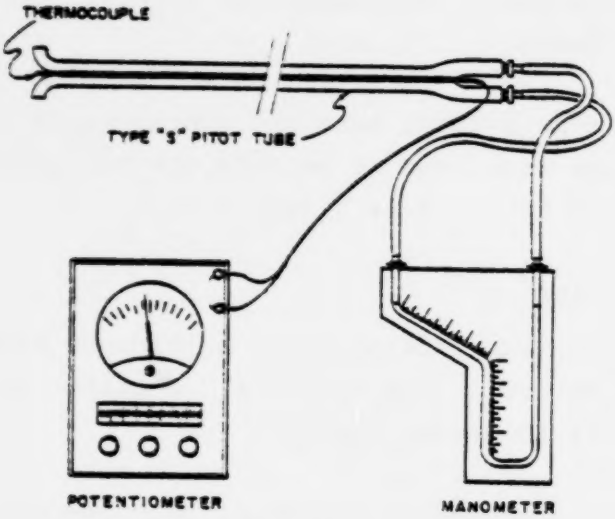


FIGURE 6-1

PRELIMINARY VELOCITY TRAIN

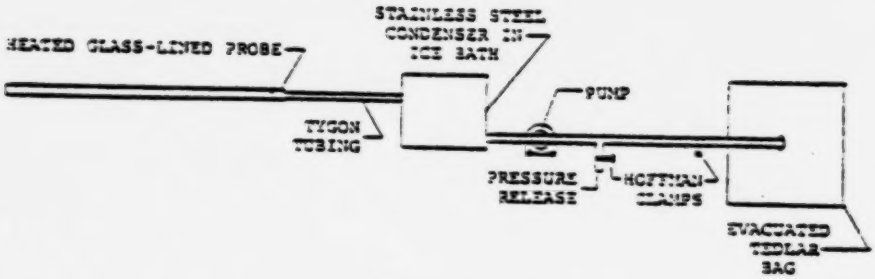


FIGURE 6-2

TEDLAR BAG SAMPLING TRAIN

6.5 Moisture in Stack Gas

Preliminary determination of the stack gas moisture content was performed in accordance with EPA Method 4 (Determination of Moisture in Stack Gases). The method employs condensation and adsorption techniques. The sampling apparatus, as shown in Figure 6-3, includes a heated probe with glass wool packing in a tube connected to the probe outlet, tygon tubing, four impingers, gas pump and a dry gas meter.

The sample is drawn through the heated probe to prevent condensation and then through the glass wool to catch any solid particulate matter. The sample is then condensed in the first two impingers, which are filled with 100 ml of distilled water each and submerged in an ice bath. The third impinger serves as an extra container for carry-over, should the moisture condensation be appreciable. The gas then passes through the fourth impinger which contains 300 gms. of silica gel for adsorbing any additional moisture. The sample gas finally passes through the gas pump and the dry gas meter where volumetric measurement of the sampled gas is taken.

Moisture determinations were also made concurrently with all EPA Method 5 particulate and organic tests.

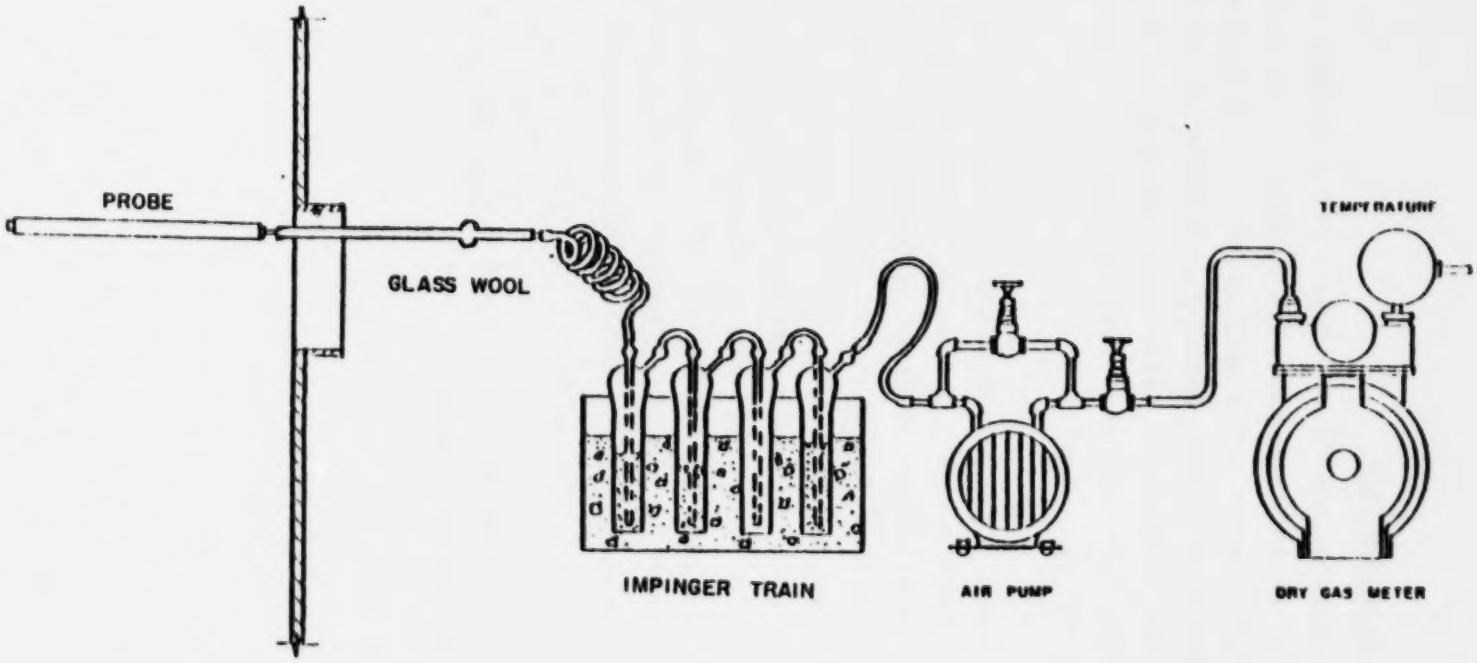


FIGURE 6-3

PRELIMINARY MOISTURE TRAIN

6.6 Particulate Method

The particulate and chloroform soluble organic concentrations were determined in accordance with guidelines outlined in EPA Method 5 (Determination of Particulate Emissions from Stationary Sources).

The sampling apparatus consisted of a probe, cyclone bypass, filter, four impingers, dry gas meter, vacuum pump and flow meter (see Figure 6-4). The probe was 5 ft. in length and glass lined. The stainless steel button-hook type probe tip was connected by a stainless steel coupling with Teflon packing to the probe. The probe consisted of 5/8 inch outside diameter tube with a ground balljoint on one end. The probe was logarithmically wound from the entrance end with 26-gauge nickel-chromium wire. During sampling, the wire was connected to a variable transformer to maintain a gas temperature of 250°F in the probe. The wire wound tube was wrapped with fiberglass tape and encased in a 1-inch-OD stainless steel casing for protection. The nozzle was attached to the end of the probe casing.

The probe connected to a cyclone bypass which connected to a very coarse fritted glass filter holder which contained a tared glass fiber filter. The filter was contained in an electrically heated enclosed box which was thermostatically maintained at a temperature of 250°F to prevent condensation.

Attached to the heated box was an ice bath containing four impingers connected in series with glass balljoints. The first impinger received the gas stream from the filter. This impinger was of the Greenburg-Smith design modified by replacing the tip with a 1/2 inch ID glass tube extending to 0.5 inches from the bottom of the flask. This impinger was initially filled with 100 milliliters of distilled water. The second impinger was of the Greenburg-Smith design and, like the first, was initially filled with 100 milliliters of distilled water. The third impinger, which was left dry, was a Greenburg-Smith impinger modified like the first. The fourth

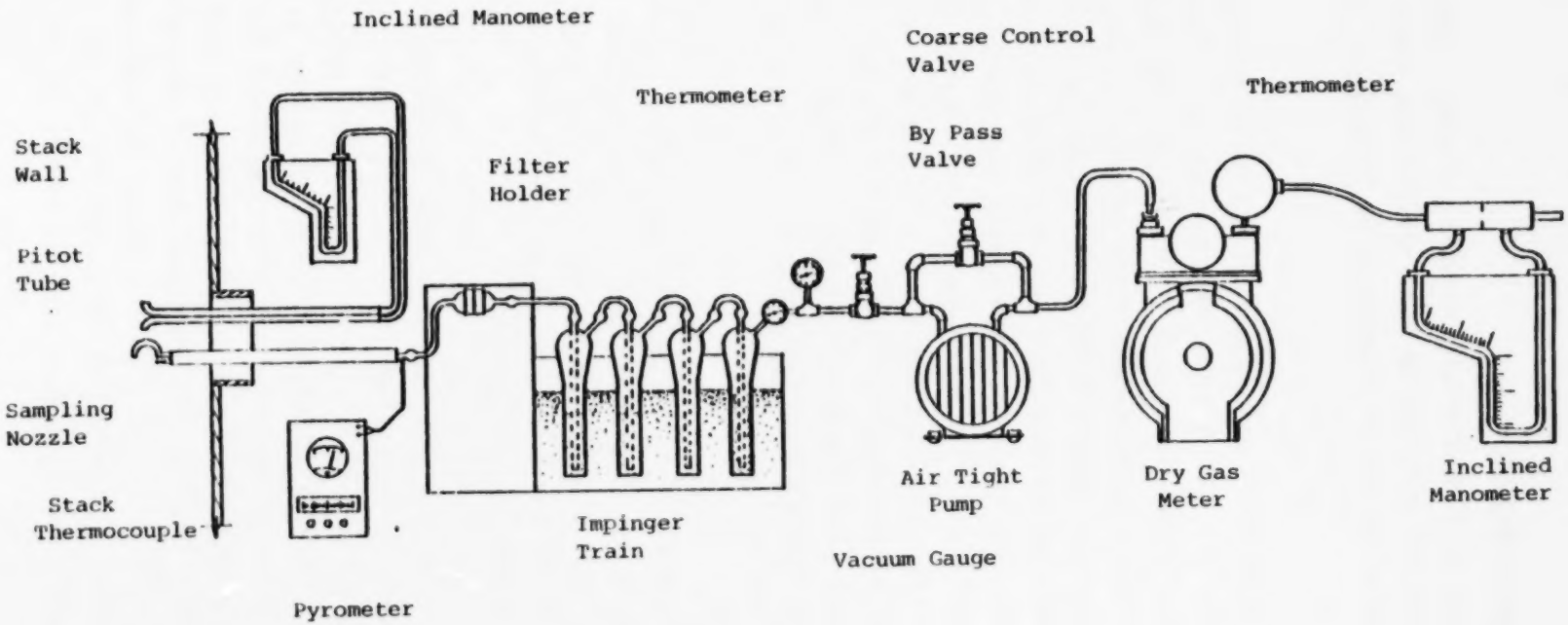


FIGURE 6-4

PARTICULATE SAMPLING TRAIN

impinger was also a Greenburg-Smith impinger modified like the first and contained dry silica gel.

From the fourth impinger the effluent stream flowed through a check valve; flexible rubber vacuum tubing; vacuum gauge; a needle valve; a leakless vacuum pump rated at 4 cubic feet per minute at 0 inches of mercury gauge pressure and 0 cubic feet per minute at 26 inches of mercury gauge pressure and connected in parallel with a bypass valve; and a dry gas meter rated at 0.1 cubic foot per revolution. A calibrated orifice completed the train and was used to measure instantaneous flow rates. The three thermometers were dial type with a range of 25° to 125°F. A fourth thermometer in the heated portion of the box has a range up to 500°F. The dual manometer across the calibrated orifice is an inclined-vertical type graduated in hundredths of an inch of water from 0 to 1.0 inch and in tenths from 1 to 10 inches.

Once completely assembled, the sampling train was leak-checked to insure collection of a representative flue gas sample. To perform the leak-check, the vacuum pump was started and the nozzle orifice covered to insure an air-tight seal. After bringing the vacuum pressure up to 15 psi, the dry gas meter was checked for any air leaks. Once the required leak check was performed, the probe was inserted into the duct at the specific sampling point. Velocity and temperature measurements of the flue gas at the pitot head were recorded and a sampling rate determined for isokinetic sampling.

6.6.1 Test Data

During each run the following readings were obtained at each point:

1. Point designation
2. Clock time
3. Dry gas meter reading (CF)
4. Velocity head (ΔP in inches water)
5. Desired pressure drop across orifice ΔH in inches water)

6. Actual pressure drop across orifice
   ΔH in inches water)
7. Dry gas temperature (^{o}F) gas meter inlet
8. Dry gas temperature (^{o}F) gas meter outlet
9. Vacuum pump gauge reading (in. Gh)
10. Filter box temperature (^{o}F)
11. Dry gas temperature (^{o}F) at the discharge of last impinger
12. Stack temperature (^{o}F)
13. Stack pressure (inches water)

The relationship of ΔP reading with the ΔH reading is a function of the following variables:

1. Orifice calibration factor
2. Gas meter temperature
3. % moisture in the flue gas
4. Ratio of flue gas pressure to barometric pressure
5. Stack temperature
6. Sampling nozzle diameter

A nomograph was used to correlate all the above variables such that a direct relationship between ΔP and ΔH was determined by the sampler within fifteen seconds and isokinetic conditions maintained throughout the test.

6.6.2 <u>Sample Recovery for Particulate and Chloroform Soluable Organics</u>

The Particulate and chloroform soluble organic test trains generated the following samples:

1. Acetone wash of the nozzle, probe and front half filter holder in sealed, labeled containers.
2. Filter sealed and labeled in a petri dish.
3. Acetone wash of the back half filter holder, impinger lines and impinger in sealed labeled containers.
4. Water solutions from the impingers placed in sealed, labeled containers.

6.7 POM Sampling Method

The POM sampling train was utilized for the collection of polycyclic organic material in the flue gas, before and after the particulate scrubber. The POM sampling train, as shown in Figure 6-5 consisted of a Method 5 train with an XAD-2 adsorbent module located downstream of the filter and condenser and upstream of the impingers. Utilizing this arrangement, POM emissions could be determined by analysis of the probe wash, filter catch, condensate, and adsorbent sampler catch. The impingers were only used to cool and dry the stack gases before they entered the dry gas meter.

The POM train used in the field consisted of a heated glass-lined probe with a stainless steel nozzle at the probe head, a heated filter assembly, one Greenburg-Smith type condenser impinger, the adsorbent sampler and four additional impingers.

In order to insure adequate POM collection efficiency in the adsorbent sampler, the flue gas temperature had to be kept as low as possible without condensing large quantities of water vapor. For this reason, a condenser (Greenburg-Smith impinger) was used between the filter and the adsorbent sampler. Connected to the impinger assembly was an umbilical, vacuum pump, dry gas meter and an orifice. All connections in the filter, adsorber and impinger assemblies were glass. Thermal control at the probe and the filter assembly was maintained in a heated mode at 325°F (versus 250°F when using the EPA Method 5 sampling train). Maintaining the probe and filter at the higher temperature prevented condensation and/or adsorption of SO_3 and POM (followed by the destructive reaction of SO_3 with POM) in these components. Thermocouple connections at the probe head, the inlet to the filter assembly, the inlet to the adsorber, the fourth impinger outlet and the inlet-outlet of the dry gas meter, allowed for monitoring sampled flue gas temperatures throughout the sampling train. Once completely assembled, the sampling train was leak-checked to insure collection of a representative flue gas sample.

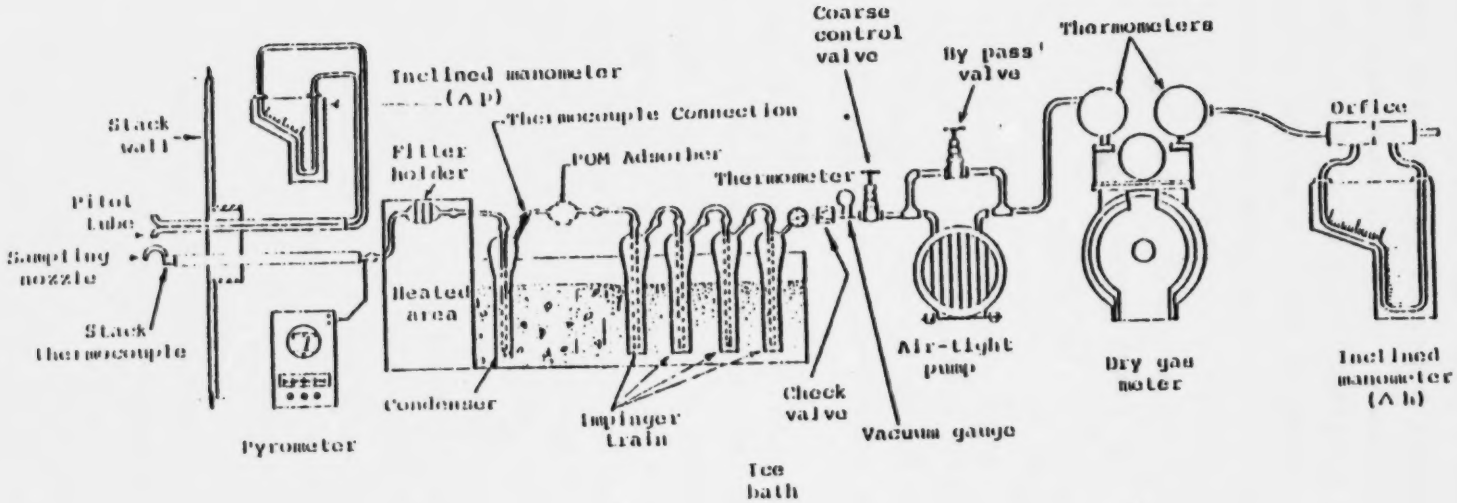


FIGURE 6-5

POM TRAIN

6.7.1 Pom Sample Recovery

Recovery of samples from the four separate sections of the POM sampling train included:

1. Methylene chloride wash of nozzle, probe and front half filter holder, sealed and labeled.
2. Acetone wash of nozzle, probe and front half filter holder, sealed and labeled.
3. Filter placed in sealed, labeled petri dish.
4. Collected condensate and methylene chloride rinse, sealed and labeled.
5. Adsorbent module, sealed and labeled.

The samples from each train were placed in sealed and labeled containers and kept in darkness to insure against photo-oxidation prior to analysis.

6.8 Benzene Soluble Organics Method

An EPA Method 5 sampling train was modified similar to the POM sampling train by insertion of an XAD-2 adsorbent module downstream of the filter and first impinger and upstream of the last four impingers.

Assembly and preliminary procedures such as leak checks were performed as per normal procedures. Velocity and temperature measurements at the flue gas at the pitot head were recorded and a sampling rate determined for isokinetic sampling.

The following tests were performed for determination of benzene soluble residue:

Test	Location	Date
1	inlet	7-16
1	outlet	7-16
2	inlet	7-17
2	outlet	7-17
3	inlet	7-30
3	outlet	7-30

6.8.1 BSO Sample Recovery

The nozzle, probe and front half filter holder were first washed with benzene, samples were labeled and sealed in light proof containers. The nozzle, probe and front half filter holder were then washed with acetone with samples labeled and sealed in appropriate containers. The filter and the adsorbent module were placed in separate, sealed and labeled containers. The back half (which includes the impingers downstream of the adsorber as well as the additional condenser) of the train was cleaned up separately with both benzene and acetone washes. These samples were labeled, sealed, and placed in light proof containers. Each train generated the following samples:

1. Front half benzene wash
2. Front half acetone wash
3. Filter
4. Adsorber
5. Back half benzene wash
6. Back half acetone wash

6.9 Determination of Sulfur in Impinger Catches

An analysis for sulfur was performed on the impinger catches of the following tests:

POM Test	1 Inlet
POM Test	1 Outlet

Previously described, modified EPA Method 5 sampling trains with XAD-2 adsorbers after the first impinger were used for the POM tests.

The samples generated for sulfur analysis from each test were:

1. Impinger water
2. Methylene chloride impinger wash

6.10 Benzene and Total Hydrocarbons

Fifteen grab samples taken with gas sampling flasks at the inlet and outlet to the coal preheater scrubber were analysed using a gas chromatograph for benzene and total hydrocarbons (THC). Benzene and THC samples were taken for the following tests:

Date	Location
7/26/78	Inlet
"	Outlet
7/27/78	Inlet
"	Outlet
7/28/78	Inlet
"	Outlet
7/29/78	Inlet
"	Outlet
7/30/78	Inlet
"	Outlet
7/31/78	Outlet only
8/2/78	Inlet
"	Outlet
8/3/78	Inlet
"	Outlet

Prior to actual sampling, these flasks were purged with flue gas Once a sample was entrapped in the flask, the flask was wrapped with aluminum foil to prevent photo oxidation, then kept cool on ice for a short time before being transported to an on-site gas chromatograph for analysis.

6.11 Coal Samples

21 coal samples were collected for each test period of the inlet and outlet preheater process. All samples were analyzed for volatile material, ash, carbon, hydrogen, and sulfur for fractions greater than 100 mesh and smaller than 100 mesh. Each coal sample was also examined by microscopy. In addition, the coal samples from Test #2 inlet and outlet were analysed by spark source

mass spectrometer (SSMS) for trace metals.

6.12 Scrubber Water

22 water samples from the inlet and outlet of the coal preheater scrubber were obtained and analyzed for Polyciclic Organic Materials. Due to funding restrictions, only six samples were actually analyzed.

6.13 Sampling Problems

Inherent to any stack test is the margin of error due to poor sampling conditions, namely; the physical arrangement of sampling locations, the characteristics of the sampled gas, and the specific industrial process involved. For the sampling of the J & L coal preheater, all of the above presented some problems.

The outlet sampling location was in the scrubber stack where temporary scaffolding had been erected to accommodate the test crew. Due to the poor quality of this scaffolding, at least one particulate test had to be scrapped.

Gas stream moisture presented a difficult problem both because it represented approximately 1/3 to 1/2 of the gas stream and because it was nearly impossible to predict moisture level in advance. The moisture content in the gas stream was directly due to the coal being processed. However, there was about a day's delay between the actual blending of the coal (prior to test) and the results of the lab's moisture analysis. Therefore, the prediction of moisture content was really based on guesswork. The assumed vs. actual moisture content for each test is shown in Table 6-1.

The prediction of moisture content is essential in order to

maintain isokinectic sampling rates. The effects of poor moisture prediction is reflected in the percent isokinetic values given for each test in Table 6-1.

Occasional shortouts of heater boxes allowed appreciable moisture collection on filters, thus hampering train collection efficiency. The high moisture also affected the manometer pitot lines. Condensed moisture and flue gas grit were forced up into the pitot tubes by the high pressure existing at the scrubber inlet (static pressures up to 11" W.C.). This condition could not be remedied by simply blowing the lines out with a pump, instead the entire pitot assembly had to be removed out of the gas stream, purged, and cleaned.

Process conditions, which are inherent to the operation of the coal preheater system, also presented major problems. Frequently sampling was interrupted by a shutdown of the system. The most typical causes of this were clogging of either the battery, feeder or preheater systems. In addition, normal process fluctuations encountered during test periods caused inconsistant flows and puffs of grit in the system. These transient effects, coupled with the high particulate and moisture loadings to begin with, were most pronounced at the scrubber inlet where frequent filter changes were required. As many as 5 and 6 filter changes were reported for some tests.

The time delays associated with the frequent filter changes at the inlet caused the inlet sampling periods to last longer than the outlet sampling periods so that it is questionable as to whether the inlet and outlet tests are actually simultaneous.

In addition, it is doubtful that fluctuations in process conditions would have the same effect on both the inlet and outlet sampling trains, i.e., puffs of grit would most likely introduce a greater error at the inlet.

Finally, it is strongly suggested that uniform, fully developed flow did not exist at the sampling locations. This could have been caused by the sampling locations themselves or, more probably, by process fluctuations. The test averages for gas velocity at the inlet range from 14 to 27 M/S. Fluctuations of a similar magnitude are conceivable during a particular test.

The errors introduced by these factors, i.e., a skewed velocity component and fluctuations in velocity, would most likely show up in the stack flowrate measurement. The inlet and outlet flowrates, in terms of dry, std. Nm^3/M should be equal. These rates are presented for each test in Table 6.2. The fact that they are not equal is evidence of the magnitude of the problems encountered.

TABLE 6-2

TEST CONDITIONS

Test		% Moisture Assumed/Actual	% Isokinectic	Stack Flow Rate Dry, STD, Nm^3/m
POM 1	Inlet	35.0/40.6	106.3	279
	Outlet	50.0/53.2	92.7	201
POM 2	Inlet	35.0/36.4	99.5	416
	Outlet	50.0/34.5	90.1	476
POM 3	Inlet	35.0/49.6	88.3	275
	Outlet	50.0/34.5	94.0	402
POM 4	Inlet	35.0/53.7	148.6	347
	Outlet	50.0/51.9	106.9	342
POM 5	Inlet	35.0/45.8	135.0	488
	Outlet	50.0/50.4	108.7	406
POM 6	Inlet	35.0/44.4	189.4	492
	Outlet	50.0/53.0	101.3	369
POM 7	Inlet	35.0/46.6	124.0	262
	Outlet	50.0/53.5	112.5	337
POM 8	Inlet	35.0/44.3	115.3	465
	Outlet	50.0/53/0	108.7	361
POM 9	Inlet	-	-	-
	Outlet	50.0/56.7	127.7	181
POM 10	Inlet	40.0/46.6	101.1	363
	Outlet	50.0/53.0	113.2	236
POM 11	Inlet	40.0/53.9	114.4	178
	Outlet	50.0/53.0	103.2	261

TABLE 6-2 (con't)

Test		% Moisture Assumed/Active	% Isokinetic	Stack Flow Rate Dry, STD. Nm^3/m
Particulate				
1	Inlet	-	-	-
	Outlet	35.0/53.2	125.2	283
2	Inlet	35.0/53.5	103.6	303
	Outlet	35.0/52.0	154.7	247
3	Inlet	-	-	-
	Outlet	50.0/58.1	117.3	312
BSO- 1	Inlet	50.0/26.4	79.4	462
	Outlet	50.0/44.5	95.9	317
2	Inlet	45.0/24.0	80.7	609
	Outlet	50.0/47.3	91.4	498
3	Inlet	35.0/35.0	110.6	325
	Outlet	50.0/50.0	112.4	270

7.0 ANALYTICAL PROCEDURES

7.1 POM Analytic Procedure

7.1.1 Particulates

Particulate emission results were analyzed using the P.O.M. Sampling Train "Particulate" methodology (gravimetrically).

The procedure involved the separate analysis of two portions of the sampling train (Front Half):

1. Nozzle, Probe, Front Half Filter Holder
2. Filter

Portion 1 apparatus was first washed with methylene chloride and the resulting samples placed in sealed, labeled sample bottles. Portion 1 apparatus was then washed with acetone and the resulting samples placed in sealed, labeled bottles. These samples were then dried to constant weight at room temperature.

The filter (portion 2) was placed in a sealed, labeled Petri Dish and then also dried to constant weight at room temperature. The combined weights of the filter catch and wash residue were in turn used in the determination of particulate loading. The POM particulate methodology is summarized in Figure 7-1.

7.1.2 Organic Analyses

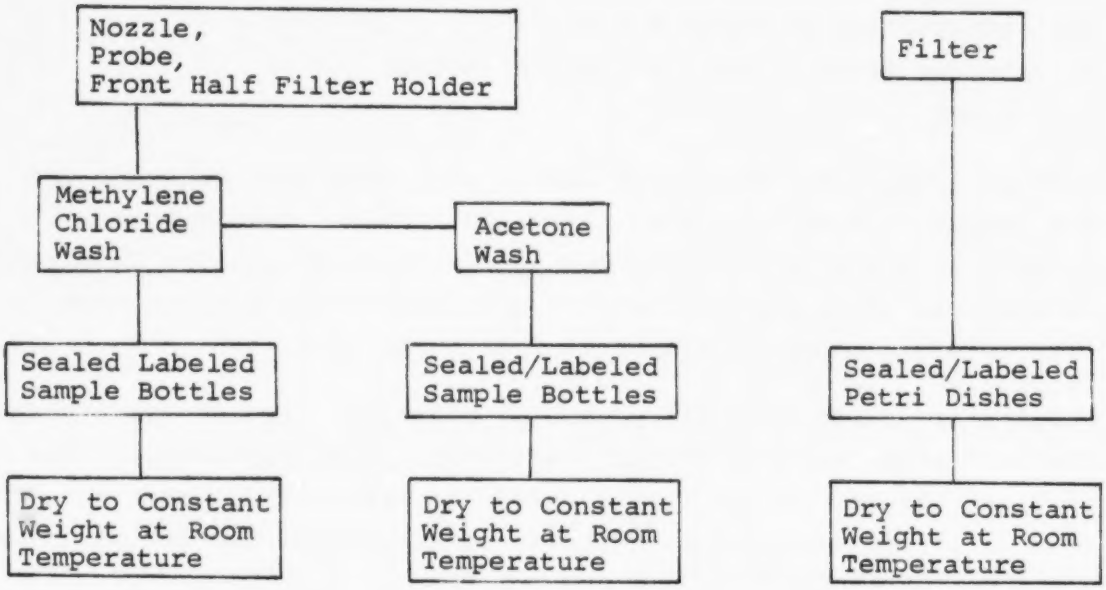
In addition to particulate loading determinations from the POM sampling train, two sets of organic analyses were performed on the samples obtained from source tests utilizing the POM train. The two organic analyses performed were Gas Chromatography/Mass Spectrometry (GC/MS) Analysis and EPA Level 1 Organic Analysis.

o Gas Chromatography/Mass Spectrometry (GC/MS) Analysis

Twenty-two (22) POM stack samples and six (6) water samples (Tests 1, 2, and 3, both inlet and outlet) were analyzed by GC/MS analysis for twenty five organic (P.O.M.) species.

FIGURE 7-1

POM SAMPLING TRAIN PARTICULATE
ANALYSIS METHODOLOGY



The methylene chloride wash of the front half was filtered and the solid filtered substance dried in a desiccator at room temperature to constant weight. The acetone washes from the front and back halves and the filter were dried in the same manner to constant weight. These constant weight samples were then combined and Soxhlet extracted using high purity methylene chloride for a period of 24 hours.

The XAD-2 adsorber was also soxhlet extracted for 24 hours using about 500 ml of methylene chloride. The condensate from the back half was liquid extracted using methylene chloride in separatory funnels fitted with Teflon stopcocks. The pH of the aqueous sample was adjusted first to 2.0 with HCl and subsequently to 12.0 with NaOH. The resulting methylene chloride extracts from all of the soxhlet and liquid extractions along with the filtrate from the Front half (CH_2Cl_2) probe wash filtration were combined and concentrated to 10-25 ml using a Kuderna Danish apparatus.

The amounts of organic material with boiling points higher than 300°C were then determined by the gravimetric analysis method (GRAV). Next, from each concentrated extract using the Kuderna apparatus, 0.5 - 8 ml aliquots were subjected to three consecutive solvent exchanges with cyclopentane. The resulting cyclopentane solutions were chromatographed (LC) on a silica gel column, collecting seven fractions by elution with solvent mixtures (pentane-methylene chloride-methanol) of increasing polarity. Gravimetric analysis was performed on the aromatic fraction (fractions 2, 3, 4) to determine species having a molecular weight (MW) less than 252 and greater than 252 due to the different detection limits used for the MS analysis. A portion of fractions 2, 3, 4 were combined for GC/MS analysis and were analyzed for 25 POM species. An OV-17 glass capillary GC column and a Finnigan Model 4023 Mass Spectrometer/Data System performed the GC/MS analysis.

A graphical representation of the GC/MS analytic procedure is shown in Figure 7.2.

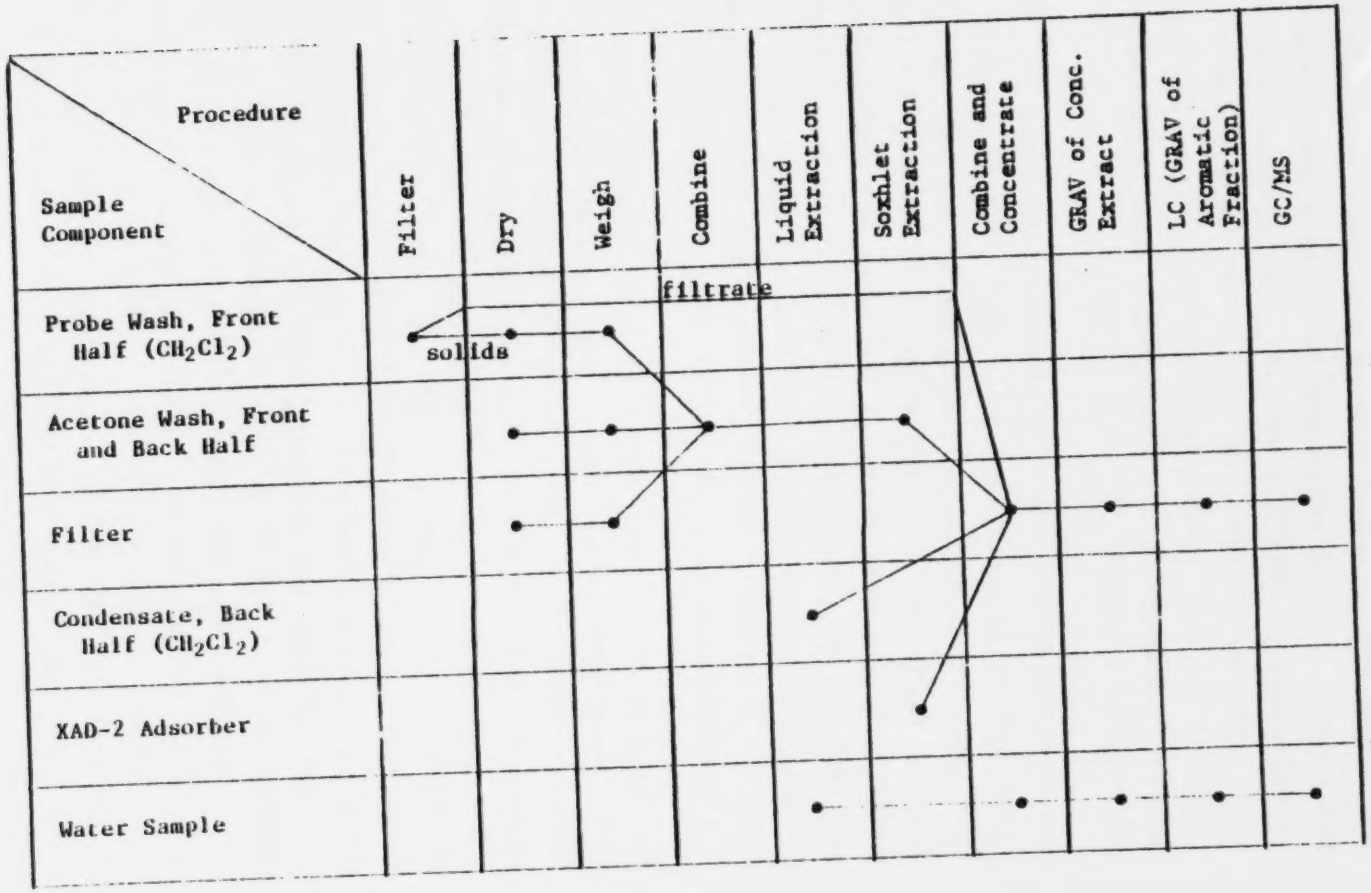


FIGURE 7-2
GC/MS Analysis

o EPA Level 1 Organic Analysis

Six samples (inlet and outlet air samples from Test No. 2, inlet and outlet, water samples from Test No. 2, stack blank, and water blank) were carried through the EPA Level 1 organic analysis.

The concentrated extract of each of the six samples were analyzed by Gas Chromatography (TCO) using a flame ionization detector to determine the quantity of organic material with boiling points in the range of 100-300°C. The amount of organic material with boiling points higher than 300°C were next determined by the gravimetric analysis method (GRAV). The IR spectra of all samples as potassium bromide micro-pellets were obtained on a Perkin-Elmer 521 grating spectrometer. Each sample was then subjected to liquid chromatography using cyclopentane solutions on a silica gel column. Seven fractions were collected by elution with solvent mixtures (pentane-methylene chloride-Methanol) of increasing polarity. All seven fractions were then individually subjected to total chromatographable organics analysis, gravimetric analysis, liquid chromatography and I.R. spectroscopy using the same methods as just described. Finally, Low Resolution Mass Spectroscopy (LRMS) analysis was carried out on a Dupont 21-110B sprctrometer. Sample sizes varied from 20 μ to 50 μ. A graphical representation of this analysis is given in Figure 7-3.

7.2 Particulate and Chloroform Soluble Organic Analysis

Particulate emission results were analyzed and characterized as either chloroform soluble or non-chloroform soluble using the State of Pennsylvania D.E.R. "Particulate" Methodology.

The procedure involved the separate analysis of the four portions of the sampling train:

1. Nozzle, Probe, Front Half Filter Holder (Acetone Wash)
2. Filter
3. Back Half, Filter Holder, Impinger lines, Impingers (Acetone Wash)
4. Impinger solutions (water)

Sample No. \ Procedure	Conc. Extract	TCO	GRAV	IR	LC	TCO (7 LC fractions)	GRAV (7 LC fractions)	IR (7 LC fractions)	LRMS (7 LC fractions)
2, Inlet	•	•	•	•	•	•	•	•	•
2, Outlet	•	•	•	•	•	•	•	•	•
H_2O, 2, Inlet	•	•	•	•	•	•	•	•	•
H_2O, 2, Outlet	•	•	•	•	•	•	•	•	•
Stack Blank	•	•	•	•	•	•	•	•	•
H_2O Blank	•	•	•	•	•	•	•	•	•

FIGURE 7-3

EPA Level 1 Organic Analysis

Samples from portions 1 and 3 were placed in sealed, labeled sample bottles and kept in a dark, refrigerated place. After refrigeration, the samples were evaporated to dryness at room temperature whereby the residue was thoroughly extracted using chloroform. The extracted samples were then divided into two separate layers of chloroform-soluble particulate and non-chloroform-soluble particulate.

The filter sample was placed in a sealed, labeled Petri Dish and stored in a dark, refrigerated place. After refrigeration the sample was thoroughly extracted using chloroform and divided into two separate layers of chloroform - soluble particulate and non-chloroform-soluble particulate.

Samples from the Impinger solutions were also placed in sealed, labeled sample bottles and stored in a dark, refrigerated place. After refrigeration, the samples were not dried but were immediately extracted using chloroform. The extracted samples were also divided into two separate layers of chloroform-soluble particulate and non-chloroform-soluble particulate.

It should be noted that the EPA Method 5 "Particulate" Analysis involved the same procedure, but only for the front half (i.e. Portions 1 and 2). See Figure 7-4 for a graphical representation of methodology previously described.

7.3 Benzene Soluble Organics Analytic Procedures

Each of the six (6) samples generated from the six (6) simultaneous modified EPA Method 5 BSO tests were analyzed for benzene soluble residue and particulate residue in the following manner:

1. The benzene wash was filtered. The filter was dried and weighed, yielding particulate weight. The benzene wash was then evaporated at room temperature and the remaining residue weighed for benzene solubles.

TABLE 2A

EPA-5 SAMPLING TRAIN ANALYTICAL METHODOLOGY FOR
EVALUATION OF CHLOROFORM-SOLUBLE AND NON-CHLOROFORM SOLUBLE PARTICULATE

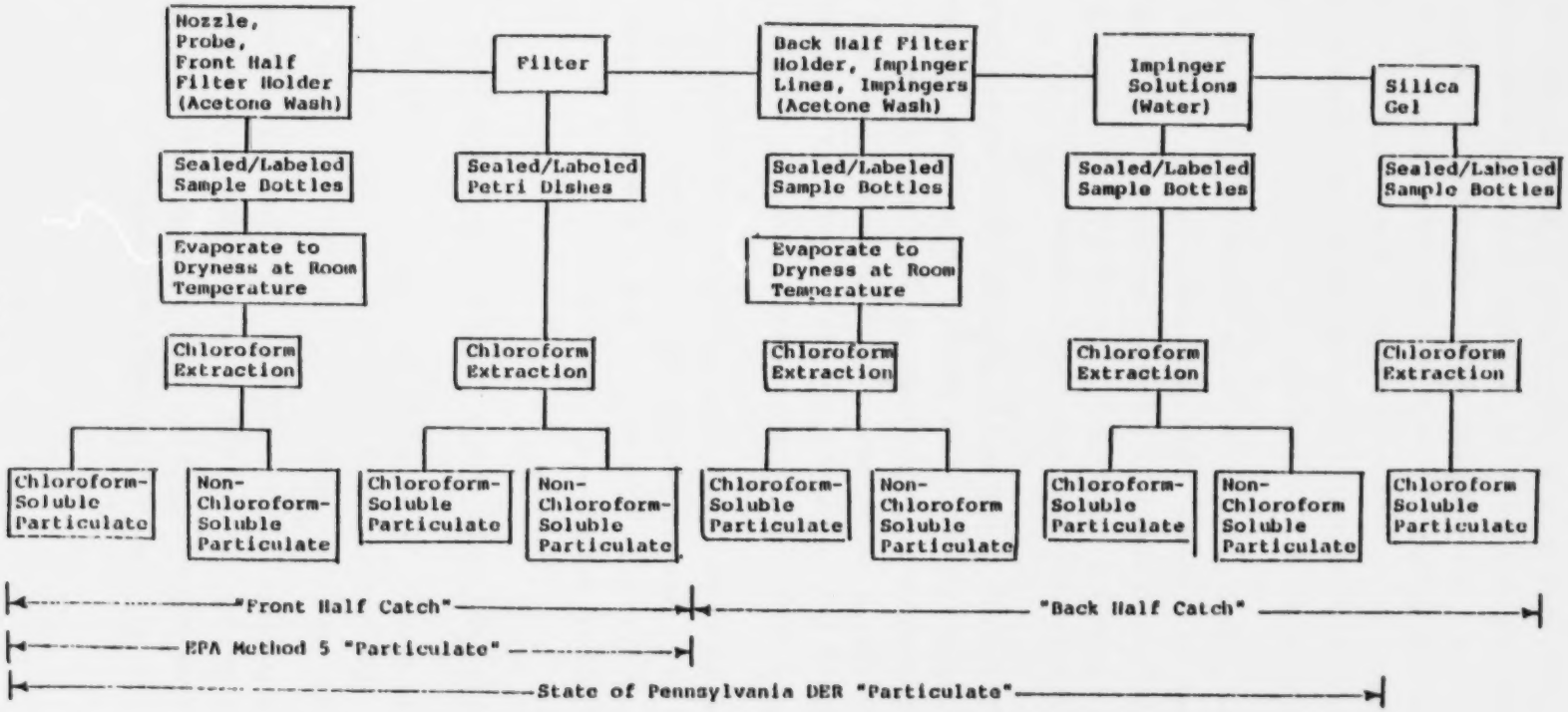


FIGURE 7-4

2. Benzene was added to the acetone wash. This mixture was filtered, the filter was dried and weighed for particulate weight. The acetone-benzene mixture was evaporated at room temperature and the remaining residue weighed. Acetone and benzene are miscible so the residue weight reflected not only the benzene solubles, but acetone solubles as well.

3. The filter was dried and weighed for particulate weight. Then, a soxhlet extraction with benzene was performed, the benzene was evaporated at room temperature and remaining residue reported as benzene soluble residue.

4. A soxhlet extraction with benzene was performed on the XAD-2 adsorbent resin. The benzene was evaporated at room temperature, the residue weighed and reported as benzene soluble residue.

5. The water sample from the back half benzene wash was extracted with benzene. The water-benzene mixture was filtered, and the filter dried and weighed. The water fraction was evaporated and the residue weighed. Residue from both the filter and water fraction are added to give particulate weight. The benzene fraction was evaporated and the residue weighed to yield benzene solubles.

6. The acetone wash was analyzed in the same manner as procedure No. 2.

7.4 Determination of Sulfur in Impinger Catches

Impinger catches from POM Test #1 inlet and outlet were analyzed for sulfur using Method 427A "Gravimetric Method with Ignition of Residue", Standard Methods for the Analysis of Water and Wastewater, 14th Edition, 1975.

The analysis involved the addition of Barium Chloride to the sample to precipitate Sulfate as Barium Sulfate. The precipitation was carried out near the boiling temperature, and after a period of digestion the precipitate was filtered, washed with water until free of chlorides, dried, and weighed as $BaSO_4$.

7.5 Benzene and Total Hydrocarbons Analytical Techniques

Fifteen (15) Grab samples taken with gas sampling flasks at the inlet and outlet to the coal preheater scrubber were analyzed for benzene and total hydrocarbons (THC). Samples were analyzed by an Analytical Instrument Division gas chromatograph that was set up in the on-site trailer. A carbopak C, 0.1% SP 1000 column at 125°C was used for determination of benzene and a sample loop was used for THC.

7.6 Scrubber Water Analysis

Of twenty-two (22) scrubber water samples taken, only six (6) were analyzed for POM's by the GC/MS technique described previously in Section 7.12. The samples from the scrubber inlet and outlet were liquid extracted, combined and concentrated, placed through gravimetric analysis, liquid chromatography (GRAV of aromatic fraction) and finally subjected to GC/MS analysis. A graphical representation of the GC/MS analytic procedure for scrubber water samples is shown in Figure 7.2.

7.7 Coal Analysis

Twenty-one (21) inlet and outlet coal samples were sieved through a 100 mesh screen and analyzed for moisture, volatile matter, ash, sulfur and carbon contents according to ASTM methods (D3173, 3174, 3175, 3177, and 3178). Table 8-41 shows the sieving and moisture analyses results. For most of the coal samples, the fraction smaller than 100 mesh was found to be ∿10% for the Inlet samples and ∿20% for the Outlet samples. The moisture contents for all samples was around 1%. The results of volatile, ash, sulfur, and carbon analyses are summarized in Tables 8-42 and 8-43. Slightly higher ash contents were observed for the Inlet samples than the corresponding Outlet samples. No substantial differences in volatile, carbon, hydrogen, and sulfur contents were observed between the

Inlet and Outlet samples.

The coal samples from Test No. 2 Inlet and Outlet were also analyzed for trace elements. The results are given in Tables 8-44 thru 8-47 A summary table with the elements over 5 mg/kg concentration for the four samples is also presented (Table 8-48). All the coal samples were also examined by stereo microscope at magnifications from 7 to 30 times. Each sample was subsequently documented with a photomacrograph taken at 6X magnification. Figure 7-5 depicts a graphic representation of the analyses performed on the coal samples.

Sample \ Analysis	Microscopy	Sieve	Volatile	Ash	Carbon and Hydrogen	Sulfur	Trace Metal
Coal from 2 Inlet and 2 Outlet	●	●	●	●	●	●	●
		>100 mesh					
		<100 mesh	●	●	●	●	●
Coal from all other Tests	●	●	●	●	●	●	
		>100 mesh					
		<100 mesh	●	●	●	●	

FIGURE 7-5

Coal Analysis

8.0 RESULTS

8.1 Particulate Results from POM Trains

The particulate results (front half only with probe and filter at 163°C) of each of the twenty-two POM tests are given in Table 8-1, listed by sampling train components. The corresponding concentration data at the source are given in Table 8-2. The major portion of the particulate was found on the filters for both inlet and outlet samples. However, substantial amounts of particulates were recovered from the probe washings for the inlet samples.

The average loading of particulates in these coal preheater effluents before the scrubber was 15.2 g/m^3, and after the scrubber was 0.84 g/m^3, i.e., about 95% of the particulates were removed by the scrubber. The actual particulate concentrations varied from 10 g/m^3 to 24 g/m^3 among tests at the inlet of the scrubber, and they varied from 0.1 g/m^3 to 1.7 g/m^3 among tests at the outlet of the scrubber. The scrubber efficiency for removing particulates in these tests varied from 99% to 83%.

TABLE 8-1

SUMMARY OF PARTICULATE EMISSIONS FROM COAL PREHEATERS (POM TRAIN)

Test	Sample	Total Particulate g	Particulate Conc. g/m^3	% Particulate Removed
1	Inlet	15.9200	12.92	
	Outlet	0.3738	0.452	96.5
2	Inlet	13.4845	10.52	
	Outlet**	0.1479	0.114	98.9
2B	Outlet	0.3195	0.287	97.3
3	Inlet	1.9878	4.398	91.3
4	Inlet*	13.6761	14.41	
	Outlet	0.8584	0.805	94.4
5	Inlet	8.8325	10.31	
	Outlet	1.4285	1.751	83.0
6	Inlet***	6.5252	14.12	
	Outlet	0.8555	1.764	87.5
7	Inlet*	16.6043	16.04	
	Outlet	1.1885	1.166	92.7
8	Inlet	10.8699	13.11	
	Outlet	1.3547	1.381	89.5
9	Outlet*	0.2472	0.299	
10	Inlet	5.0819	21.26	
	Outlet	0.2790	0.425	98.0
11	Inlet	12.9479	15.13	
	Outlet	1.0016	1.309	91.4

* Questionable data due to moisture
** Test invalid due to train leak
*** Test invalid due to insufficient sample

TABLE 8-2

PARTICULATE LOADINGS BY SAMPLING TRAIN COMPONENTS (POM TRAIN)

Test No.	Probe Wash, Front Half (CH_2Cl_2)	Probe Wash, Front Half (Acetone)	Filter
1 Inlet	3.8149 g	0.0629 g	12.0422 g
1 Outlet	0.0885	0.0422	0.2431
2 Inlet	3.8279	0.1260	9.5306
2A Outlet**	0.0764	0.0271	0.0444
2B Outlet	0.1482	0.0423	0.1290
3 Inlet	1.6649	0.0332	0.2897
3 Outlet	0.0402	0.0314	0.3374
4 Inlet*	3.3402	0.2425	10.0934
4 Outlet	0.0227	0.0521	0.7836
5 Inlet	3.9592	0.5202	4.3441
5 Outlet	0.0374	0.0420	1.3491
6 Inlet***	2.1526	0.0906	4.2820
6 Outlet	0.0244	0.0454	0.7857
7 Inlet*	3.4242	0.1600	13.0201
7 Outlet	0.0653	0.0767	1.0465
8 Inlet	2.8087	0.0368	8.0244
8 Outlet	0.0441	0.1040	1.2066
9 Outlet*	0.0618	0.0444	0.1410
10 Inlet	1.9898	0.0657	3.0264
10 Outlet	0.0459	0.0315	0.2016
11 Inlet	3.9317	0.1353	8.8809
11 Outlet	0.0542	0.0413	0.9061

* Questionable data due to moisture
** Test invalid due to train leak
*** Test invalid due to insufficient sample

8.2 Gas Chromatography/Mass Spectrometry (GC/MS) Analysis

8.2.1 Identification of POMs

The concentrations determined for the POMs analyzed for each sample are tabulated in Tables 8-5 through 8-15. The total ion chromatographs for the aromatic fractions of each sample are given in Appendix B. These concentrations were computed from calibration data by the methods described previously. For those compounds which are present in the mixture, the calibration data obtained directly are used. For the Benzofluoranthene isomers, the calibration data for Benzo-(a) pyrene were used for the reasons discussed previously. The remaining compounds have estimated calibration curves based on their molecular weight. The use of this estimation procedure had a minimal impact on the results obtained since most of compounds for which it was used were not found in any of the samples. The POMs not found include cholanthrene, dibenzcarbazole, and dibenzacridines. The following discussion presents the efforts made to verify the absence of these compounds.

Cholanthrene (mw 254) was not detected in any of the samples. Some of the inlet and outlet samples show the presence of several 254 POMs in the proper retention time region for cholanthrene, but the spectra and the relative elution order are those of binaphthyls. The concentration of the binaphthyls is low, on the order of 0.1 to 0.2 ug/mL in the most concentrated stack sample. Sample 8, inlet, was examined before liquid chromatography separation to look for the presence of other mw 254 POMs. Figure 8-1 shows the ion chromatograph for mw 252

and 254 for the #8 inlet sample prior to LC separation. The three peaks marked with arrows on the mw 254 ion chromatograph are the same as those seen in the samples after LC and their spectra best fit the various binaphthyls. Several additional mw 254 POMs are seen, but at levels below that of the binaphthyls. Extrapolation of those levels to the samples examined gives a concentration level at or below the detection limit. Thus, no concentration values are given in the tables for cholanthrene.

The analysis of 7,12-dimethyl benz(a)anthracene is complicated by the large number of unresolved isomers of dimethyl and ethyl isomers present, such as dimethyl chrysenes, etc.. Figure 8-2 shows the two major ions in the mass spectra of the dimethyl benzanthracene and dimethyl chrysene isomers, with the arrows on the mw 256 ion chromatogram indicating the location of the $C_{20}H_{16}$ isomers. Tests where small amounts of 7,12-dimethyl benz(a)anthracene (the $C_{20}H_{16}$ isomer of interest) were added to one of the samples (#8 inlet after LC) were unsuccessful at pinpointing the location of this isomer within the cluster of $C_{20}H_{16}$ POMs. To give an estimate of the level of these POMs present, the area for each of the isomers noted in Figure 8-2 were summed and the concentration computed using the approximate response/ng value based on the molecular weight dependence of POM response factors.

Neither dibenzacridine nor dibenzocarbazole were found in any of the samples. It may have been possible that dibenzocarbazole, which has its molecular weight ion at mw 257, may be present in these samples but was obscured by the abundance of methyl-benzopyrenes and methyl perylenes (mw 266). The methyl

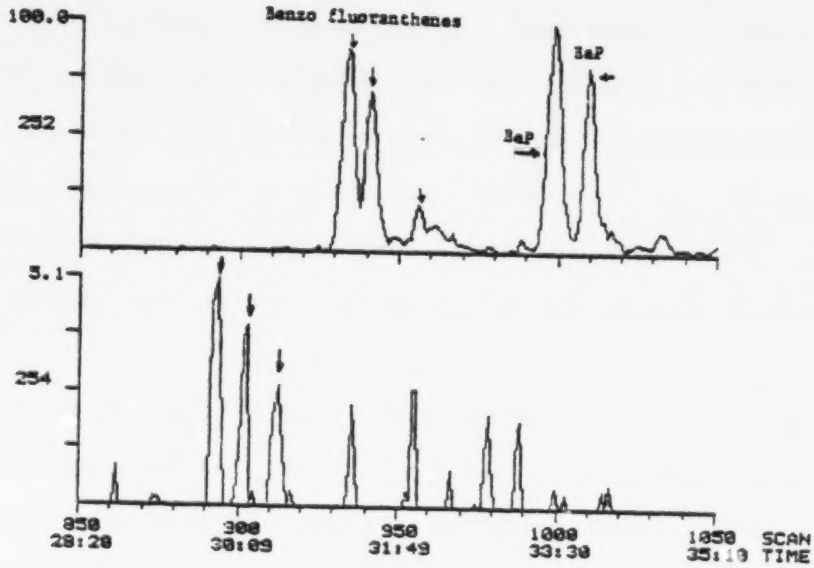


Figure 8-1

Ion Chromatogram of mw 252 and 25^d in sample #8-Inlet Whole Extract

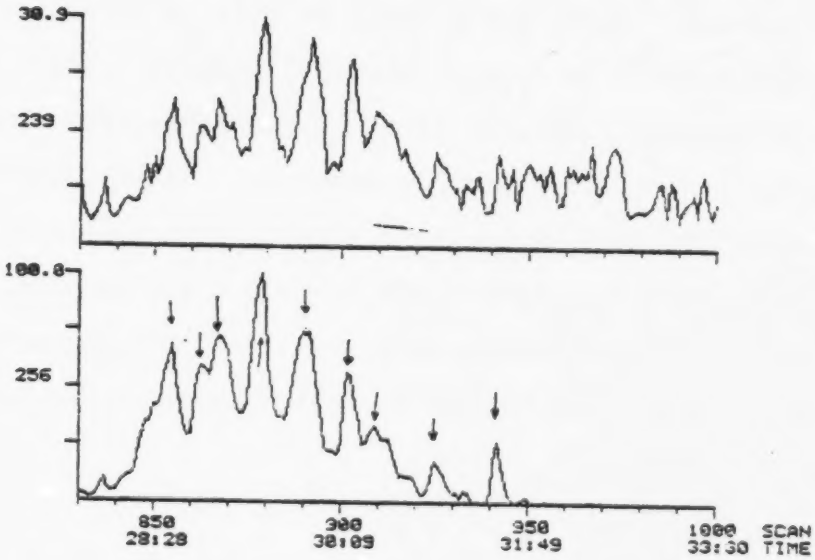


Figure 8-2

Ion Chromatogram of mw 256 in Sample #8-Inlet, Whole Extract

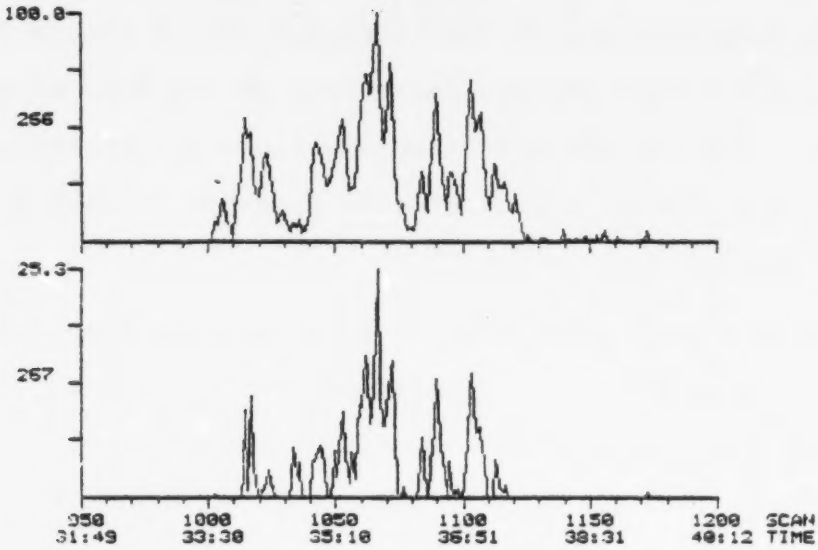


Figure 8-3

Ion Chromatogram of mw 266 and 267 in Sample #8-Inlet, Whole Extract

benzopyrenes elute in the same retention time region as dibenzocarbazole with the ^{13}C containing of isotope of the molecular ion at mw 267. This amounts to 23% of the molecular ion at mw 266 so that the potential interferences on the dibenzocarbazole measurement are quite great. In the region where the dibenzocarbazole should elute, all of the mw 267 peaks correlate with isotope peaks from mw 266 POMs as shown in Figure 8-3, for the #8-inlet sample without LC separation. Thus there is no evidence to indicate the presence of dibenzocarbazole in these samples.

Dibenzacridine with molecular ion at mw 279 was also not found in any of the samples. An evaluation of the #8-inlet sample before the LC fractionation and dilution carried out as described above, showed that all mw 279 peaks could be accounted for by other species and no evidence of dibenzacridine could be found.

8.2.2 Detection Limits

The limits of detection vary depending upon the species, the sample preparation, and the definition of the limit of detection. The instrumental detection limits for the subject POM species range from 30 to 200 picograms injected onto the column. The limit of detection is defined as the lowest level permitting MS confirmation from the mass spectra. In more appropriate terms, the limit of detection should be defined with respect to the original sample. For example; one could compute the detection limits in the gas using the instrumental detection limits above and standard analytical conditions, such as 1 m^3 of the gas sampled, volume of combined extract reduced to 15 mL of which 1 ml is fractionated by LC (resulting in 30 mL eluent) and 2 μL

TABLE 8-3

DETECTION LIMITS OF GC/MC ANALYSIS

Sample No.	Detection Limit (mg/m^3) Species <252 m/e	Species >252 m/e
1, Inlet	.004	.030
1, Outlet	.003	.018
2, Inlet	.004	.023
2, Outlet	.001	.006
2B, Outlet	.002	.013
3, Inlet	.010	.070
3, Outlet	.004	.028
4, Inlet	.009	.063
4, Outlet	.011	.070
5, Inlet	.011	.070
5, Outlet	.013	.088
6, Inlet	.018	.120
6, Outlet	.012	.077
7, Inlet	.010	.064
7, Outlet	.008	.053
8, Inlet	.012	.077
8, Outlet	.010	.064
9, Outlet	.005	.036
10, Inlet	.009	.063
10, Outlet	.007	.046
11, Inlet	.005	.036
11, Outlet	.006	.039

is injected into the GC/MS for analysis. For a 30 pg limit and a 2 μL injection, the concentration would be 15 pg/μL or 15 ng/mL in the LC eluent. The total LC eluent would contain 450 ng which is 1/15 of that in the extract (i.e., 6.75 μg is in the extract). Thus, the limit of detection in the gas phase would be about 7 $\mu g/m^3$. The detection limits thus calculated for the stack air samples range from 0.8 $\mu g/m^3$ to 18 $\mu g/m^3$ for POM species having a mw <252 and from 6 $\mu g/m^3$ to 120 $\mu g/m^3$ for species having a mw >252, depending on the volume of concentrated extract and the volume of air sampled. Table 8-3 shows the detection limit values for each sample computed in the manner described above.

8.2.3 Total POM (128< mw <302)

Total POM concentrations (128< mw <302) of the 22 POM-train tests are summerized in Table 8-4. Inlet concentrations ranged from 170 mg/Nm^3 to 22 mg/Nm^3 with an average of 64 mg/Nm^3. Outlet concentrations ranged from 104 mg/Nm^3 to 3.2 mg/Nm^3 with an average of 37 mg/Nm^3. Scrubber efficiency based on total POM concentration ranged from 17.8 to 71.6. The average scrubber efficiency was 40%.

Total POM concentrations for each of the six water samples are also summarized in Table 8-4. Inlet concentrations ranged from 0.54 mg/L to 0.30 mg/L with the average being 0.40 mg/l. Outlet concentrations ranged from 0.12 mg/L to 0.04 mg/L with the average being 0.08 mg/L.

TABLE 8-4

SUMMARY OF TOTAL POM (123< mw <302) CONCENTRATION IN COAL PREHEATER SAMPLES

STACK SAMPLES

Test	Sample	mg/Nm^3	g/Hr	g/M-ton
1	Inlet	26.73	447.69	8.243
	Outlet	21.98	264.94	4.683
2	Inlet	21.96	548.12	6.694
	Outlet- B	17.80	637.00	7.794
3	Inlet	66.86	1104.67	13.238
	Outlet	18.96	457.67	5.495
4	Inlet*	144.58	3005.94	27.575
	Outlet	61.36	1260.07	11.565
5	Inlet	68.69	2009.86	18.533
	Outlet	103.95	2534.34	23.379
6	Inlet***	71.61	2114.18	19.582
	Outlet	31.95	707.33	6.544
7	Inlet*	52.82	829.16	10.141
	Outlet	40.04	809.66	9.891
8	Inlet	169.22	4717.3	43.31
	Outlet	63.47	1375.28	12.639
9	Outlet*	80.994	883.14	30.348
10	Inlet	45.71	995.18	12.189
	Outlet	37.51	530.70	6.494
11	Inlet	37.94	405.37	4.9605
	Outlet	27.27	426.83	5.245

* Questionable data due to moisture

*** Test invalid due to insufficient sample

TABLE 8-4
(continued)

WATER SAMPLES

Test	Samples	mg/L
1	Inlet	0.38
	Outlet	0.09
2	Inlet	0.55
	Outlet	0.04
3	Inlet	0.30
	Outlet	0.11

8.2.4 Selected POM

Among the compounds found in the coal preheater air and water samples, the most abundant species were naphalene, anthracene, and phenanthrene. Lesser amounts of fluorene, pyrene, benzanthracene, chrysene, and benzopyrenes were also found in all the air samples. In the water samples, only the low molecular weight species, such as napthacene and anthracene, were found, with concentrations below the PPM level.

Tables 8-5 through 8-15 summarize the POM concentrations found in the air samples, while the water sample concentrations are presented in Table 8-16.

TABLE 8-5

COAL PREHEATER SAMPLES

POM Analysis

Test No.: 1
Description: POM #1
Process Conditions: 54/277
Date: 7/18/78

Species	mw	INLET mg/m^3	INLET g/	INLET g/M ton	OUTLET mg/m^3	OUTLET	OUTLET g/M ton	%
Naphthalene	128	19.6	328.4	6.04	14.1	170.0	3.120	28.1
Fluorene	166	0.5	8.39	0.154	1.3	15.65	0.288	---
Anthracene/Phenanthrene	178	3.5	58.5	1.074	5.2	62.69	1.150	---
Fluoranthene	202	0.34	5.72	0.104	0.37	4.459	0.0820	---
Pyrene	202	0.35	5.85	0.108	0.38	4.581	0.0839	---
Benz(a)anthracene/(c)phenanthrene	228	0.25	4.19	0.077	0.11	1.324	0.0243	56.0
Chrysene/Triphenylene	228	0.42	7.03	0.129	0.19	2.291	0.0421	54.8
Benzo(b or k)fluoranthene	252	0.32	5.35	0.099	0.07	0.844	0.0155	78.1
Benzo(j)fluoranthene	252	---	---	---	---	---	---	---
Benzo(e)pyrene	252	0.26	4.35	0.080	0.08	0.966	0.0177	69.2
Benzo(a)pyrene	252	0.18	3.02	0.055	0.06	0.721	0.0133	66.7
Cholanthrene	254	---	---	---	---	---	---	---
Dimethyl benzanthracene isomers*	256	0.57	9.57	0.176	0.12	1.447	0.0265	78.9
Dibenzo(c,g)carbazole	267	---	---	---	---	---	---	---
3-Methylcholanthrene	268	0.17	2.85	0.052	---	---	---	---
Indeno(1,2,3-cd)pyrene	276	0.09	1.51	0.028	---	---	---	---
Benzo(ghi)perylene	276	0.09	1.51	0.028	---	---	---	---
Dibenz(ah or aj) anthracenes	278	0.09	1.51	0.028	---	---	---	---
Dibenzacridines	279	---	---	---	---	---	---	---
Coronene	300	---	---	---	---	---	---	---
Dibenzo(a,h)pyrene	302	---	---	---	---	---	---	---
Dibenzo(a,i)pyrene	302	---	---	---	---	---	---	---
TOTAL		26.73	447.69	8.243	21.98	264.94	4.683	17.8

* Includes dimethyl- and ethyl-chrysenes, benzophenanthrenes, and benzanthracenes

** Process conditions reported in tons/hr

TABLE 8-6

COAL PREHEATER SAMPLES

POM Analysis

Test No. 2
Description: POM #2
Process Cond.: 82/271
Date: 7/19/78

Species	mw	INLET mg/M^3	INLET g/hr	INLET g/M Ton	OUTLET mg/m^3	OUTLET g/hr	OUTLET g/M ton	η %
Naphthalene	128	10.1	252.1	3.085	13.000	468	5.727	
Fluorene	166	1.14	28.45	0.3482	0.700	25.2	0.308	61.4
Anthracene/Phenanthrene	178	6.4	159.8	1.9547	2.800	100.8	1.233	43.8
Fluoranthene	202	0.59	14.74	0.1803	0.250	9.0	0.1101	42.4
Pyrene	202	0.52	12.97	0.1589	0.140	5.04	0.0617	26.9
Benz(a)anthracene/(c)phenanthrene	228	0.39	9.75	0.1189	0.260	9.36	0.1145	66.7
Chrysene/Triphenylene	228	0.79	19.73	0.2413	0.350	12.6	0.154	44.3
Benzo(b or k)fluoranthene	252	0.42	10.48		---			
Benzo(j)fluoranthene	252	---	---	---	---			
Benzo(e)pyrene	252	0.36	8.98	0.1099	0.120	4.32	0.0529	33.3
Benzo(a)pyrene	252	0.14	3.49	0.0428	0.073	2.63	0.0322	52.1
Cholanthrene	254	---	---	---	---			
Dimethyl benzanthracene isomers*	256	1.0	24.95	0.3052	---			
Dibenzo(c,g)carbazole	267	---	---	---	---			
3-Methylcholanthrene	268	0.03	0.748	.009142	---			
Indeno(1,2,3-cd)pyrene	276	0.02	0.499	.006094	---			
Benzo(ghi)perylene	276	0.06	1.497	.01833	---			
Dibenz(ah or aj) anthracenes	278	---	---	---	---			
Dibenzacridines	279	---	---	---	---			
Coronene	300	---	---	---	---			
Dibenzo(a,h)pyrene	302	---	---	---	---			
Dibenzo(a,i)pyrene	302	---	---	---	---			
TOTAL		21.96	548.12	6.694	17.800	637.0	7.794	18.9

* Includes dimethyl- and ethyl-chrysenes, benzophenanthrenes, and benzanthracenes.

TABLE 8-7

COAL PREHEATER SAMPLES

POM Analysis

Test No. 3
Description: POM #3
Process Conditions: 83/271
Date: 7/24/78

Species	mw	INLET mg/m^3	INLET g/M ton	INLET mg/T ton	OUTLET mg/m^3	OUTLET g/hr	OUTLET g/M ton	η %
Naphthalene	128	33	545.2	6.53	14.6	352.44	4.221	55.8
Fluorene	166	4.6	76.02	0.9092	0.67	16.19	0.1938	85.4
Anthracene/Phenanthrene	178	17.8	294.1	3.52	2.6	62.78	0.7493	85.4
Fluoranthene	202	1.3	21.50	0.2573	0.17	4.105	0.04896	86.9
Pyrene	202	1.4	23.13	0.2768	0.19	4.586	0.05496	86.4
Benz(a)anthracene/(c)phenanthrene	228	0.96	15.87	0.1898	0.16	3.865	0.04621	83.3
Chrysene/Triphenylene	228	2.1	34.70	0.4151	0.50	12.065	0.1449	76.2
Benzo(b or k)fluoranthene	252	1.3	21.50	0.2573	---	---	---	---
Benzo(j)fluoranthene	252	---	---	---	---	---	---	---
Benzo(e)pyrene	252	1.1	18.19	0.2178	0.07	1.678	0.0202	93.6
Benzo(a)pyrene	252	0.67	11.07	0.1324	---	---	---	---
Cholanthrene	254	---	---	---	---	---	---	---
Dimethyl benzanthracene isomers*	256	2.3	38.01	0.4551	---	---	---	---
Dibenzo(c,g)carbazole	267	---	---	---	---	---	---	---
3-Methylcholanthrene	268	---	---	---	---	---	---	---
Indeno(1,2,3-cd)pyrene	276	0.08	1.320	0.01584	---	---	---	---
Benzo(ghi)perylene	276	0.25	4.132	0.04946	---	---	---	---
Dibenz(ah or aj) anthracenes	278	---	---	---	---	---	---	---
Dibenzacridines	279	---	---	---	---	---	---	---
Coronene	300	---	---	---	---	---	---	---
Dibenzo(a,h)pyrene	302	---	---	---	---	---	---	---
Dibenzo(a,i)pyrene	302	---	---	---	---	---	---	---
TOTAL		66.86	1104.67	13.238	18.96	457.67	5.495	71.6

* Includes dimethyl- and ethyl-chrysenes, benzophenanthrenes, and benzanthracenes.

TABLE 8-8

COAL PREHEATER SAMPLES

POM Analysis

Test No. 4
Description: POM #4
Process Conditions: 109-260
Date: 7/25/78

Species	mw	INLET mg/m^3	INLET g/hr	INLET g/M ton	OUTLET mg/m^3	OUTLET g/hr	OUTLET g/M ton	%
Naphthalene	128	80	1663.3	15.29	43	883.1	8.093	46.3
Fluorene	166	11.5	239.1	2.198	3.5	71.85	0.6594	69.6
Anthracene/Phenanthrene	178	40	831.4	7.643	8.4	172.5	1.5836	79
Fluoranthene	202	2.7	56.15	0.5145	0.9	18.46	0.1698	66.7
Pyrene	202	2.4	49.89	0.4596	0.82	16.83	0.1549	65.8
Benz(a)anthracene/(c)phenanthrene	228	1.2	24.95	0.2298	0.45	9.253	0.0849	62.5
Chrysene/Triphenylene	228	2.3	47.81	0.4391	0.90	18.46	0.1698	60.9
Benzo(b or k)fluoranthene	252	0.99	20.59	0.1883	0.43	8.831	0.0809	56.6
Benzo(j)fluoranthene	252	---	---	---	---	---	---	---
Benzo(e)pyrene	252	0.8	16.65	0.1529	0.39	8.029	0.7343	51.3
Benzo(a)pyrene	252	0.29	6.033	0.0555	0.17	3.493	0.03202	41.4
Cholanthrene	254	---	---	---	---	---	---	---
Dimethyl benzanthracene isomers*	256	2.4	49.89	0.45958	2.4	49.26	0.4521	---
Dibenzo(c,g)carbazole	267	---	---	---	---	---	---	---
3-Methylcholanthrene	268	---	---	---	---	---	---	---
Indeno(1,2,3-cd)pyrene	276	---	---	---	---	---	---	---
Benzo(ghi)perylene	276	---	---	---	---	---	---	---
Dibenz(ah or aj) anthracenes	278	---	---	---	---	---	---	---
Dibenzacridines	279	---	---	---	---	---	---	---
Coronene	300	---	---	---	---	---	---	---
Dibenzo(a,h)pyrene	302	---	---	---	---	---	---	---
Dibenzo(a,i)pyrene	302	---	---	---	---	---	---	---
TOTAL		144.58	3005.94	27.575	61.36	1260.07	11.565	57.6

* Includes dimethyl- and ethyl-chrysenes, benzophenanthrenes, and benzanthracenes.

TABLE 8-9

COAL PREHEATER SAMPLES

POM Analysis

Test No. 5
Description: POM #5
Process Conditions: 109/288
Date: 7/26/78

Species	mw	INLET mg/m^3	INLET g/hr	INLET g/M ton	OUTLET mg/m^3	OUTLET g/hr	OUTLET g/M ton	%
Naphthalene	128	41	1199.7	10.99	69	1682.4	15.486	-
Fluorene	166	4.9	143.38	1.324	4.1	99.97	0.9192	16.3
Anthracene/Phenanthrene	178	14	409.64	3.777	20	487.6	4.496	-
Fluoranthene	202	1.1	32.20	0.2967	1.7	41.46	0.3822	-
Pyrene	202	0.97	283.95	0.2618	1.5	36.56	0.3367	-
Benz(a)anthracene/(c)phenanthrene	228	0.66	19.323	0.1778	1.2	29.26	0.2698	-
Chrysene/Triphenylene	228	1.5	43.908	0.4046	2.3	56.06	0.5145	-
Benzo(b or k)fluoranthene	252	1.2	35.108	0.3237	1.1	26.81	0.2473	8.3
Benzo(j)fluoranthene	252	---	---	---	---	---	---	---
Benzo(e)pyrene	252	9.98	28.667	0.2643	0.45	10.977	0.1009	54.1
Benzo(a)pyrene	252	0.58	16.964	0.1564	---	---	---	---
Cholanthrene	254	---	---	---	---	---	---	---
Dimethyl benzanthracene isomers*	256	1.8	52.66	0.4856	2.6	63.389	0.5845	---
Dibenzo(c,g)carbazole	267	---	---	---	---	---	---	---
3-Methylcholanthrene	268	---	---	---	---	---	---	---
Indeno(1,2,3-cd)pyrene	276	---	---	---	---	---	---	---
Benzo(ghi)perylene	276	---	---	---	---	---	---	---
Dibenz(ah or aj) anthracenes	278	---	---	---	---	---	---	---
Dibenzacridines	279	---	---	---	---	---	---	---
Coronene	300	---	---	---	---	---	---	---
Dibenzo(a,h)pyrene	302	---	---	---	---	---	---	---
Dibenzo(a,i)pyrene	302	---	---	---	---	---	---	---
TOTAL		68.69	2009.86	18.533	103.95	2534.34	23.379	---

* Includes dimethyl- and ethyl-chrysenes, benzophenanthrenes, and benzanthracenes.

TABLE 8-10

COAL PREHEATER SAMPLES

POM Analysis

Test No. 6
Description: POM #6
Process Conditions: 108/288
Date: 7/27/78

Species	mw	INLET mg/m^3	INLET g/hr	INLET g/M ton	OUTLET mg/m^3	OUTLET g/hr	OUTLET g/M ton	η %
Naphthalene	128	40	1180.7	10.94	13	287.8	2.663	67.5
Fluorene	166	4.3	126.51	1.174	1.7	37.65	0.3482	60.5
Anthracene/Phenanthrene	178	15	442.8	4.097	8.1	179.30	1.6585	46.0
Fluoranthene	202	1.1	32.48	0.3007	0.8	17.71	0.1639	27.3
Pyrene	202	1.2	35.43	0.3277	0.91	20.14	0.1863	24.2
Benz(a)anthracene/(c)phenanthrene	228	0.88	25.99	0.2403	0.63	13.95	0.1291	28.4
Chrysene/Triphenylene	228	2.3	67.90	0.6294	1.7	37.65	0.3482	26.1
Benzo(b or k)fluoranthene	252	1.2	35.43	0.3277	0.97	21.45	0.1988	19.2
Benzo(j)fluoranthene	252	---	---	---	---	---	---	---
Benzo(e)pyrene	252	1.5	44.28	0.4096	0.88	19.46	0.1803	41.3
Benzo(a)pyrene	252	0.53	15.65	0.1499	0.37	8.192	0.0759	30.2
Cholanthrene	254	---	---	---	---	---	---	---
Dimethyl benzanthracene isomers*	256	3.1	91.53	0.8492	2.8	61.988	0.5735	9.7
Dibenzo(c,g)carbazole	267	---	---	---	---	---	---	---
3-Methylcholanthrene	268	0.29	8.573	0.6794	---	---	---	---
Indeno(1,2,3-cd)pyrene	276	---	---	---	---	---	---	---
Benzo(ghi)perylene	276	0.21	6.214	0.05745	0.09	1.991	0.01848	57.1
Dibenz(ah or aj) anthracenes	278	---	---	---	---	---	---	---
Dibenzacridines	279	---	---	---	---	---	---	---
Coronene	300	---	---	---	---	---	---	---
Dibenzo(a,h)pyrene	302	---	---	---	---	---	---	---
Dibenzo(a,i)pyrene	302	---	---	---	---	---	---	---
TOTAL		71.61	2114.18	19.582	31.95	707.33	6.544	55.4

* Includes dimethyl- and ethyl-chrysenes, benzophenanthrenes, and benzanthracenes.

TABLE 8-11

COAL PREHEATER SAMPLES

POM Analysis

Test No. 7
Description: POM #7
Processs Conditions: 82/288
Date: 7/28/78

Species	mw	INLET mg/m^3	INLET g/hr	INLET g/M ton	OUTLET mg/m^3	OUTLET g/hr	OUTLET g/M ton	η %
Naphthalene	128	27	423.8	5.195	15	303.36	3.7116	44.4%
Fluorene	166	3	47.08	0.5745	3.9	78.88	0.9641	---
Anthracene/Phenanthrene	178	13	204.1	2.498	13	262.9	3.2171	---
Fluoranthene	202	1.4	21.999	0.2688	0.66	13.335	0.1634	52.9%
Pyrene	202	1.3	20.41	0.2498	0.74	14.968	0.1833	43.1
Benz(a)anthracene/(c)phenanthrene	228	0.95	14.92	0.1823	0.74	14.968	0.1833	22.1
Chrysene/Triphenylene	228	2.0	31.39	0.3842	1.5	30.336	0.3712	25.0
Benzo(b or k)fluoranthene	252	1.0	15.69	0.1923	1.1	22.226	0.2723	---
Benzo(j)fluoranthene	252	---	---	---	0.06	1.2156	0.0148	---
Benzo(e)pyrene	252	1.0	15.69	0.1923	0.88	17.781	0.2178	12.0
Benzo(a)pyrene	252	0.27	4.237	0.05195	0.47	9.525	0.1164	---
Cholanthrene	254	---	---	---	---	---	---	---
Dimethyl benzanthracene isomers*	256	1.9	29.846	0.3647	1.7	34.382	0.4206	10.5
Dibenzo(c,g)carbazole	267	---	---	---	---	---	---	---
3-Methylcholanthrene	268	---	---	---	0.11	2.2226	0.02723	---
Indeno(1,2,3-cd)pyrene	276	---	---	---	---	---	---	---
Benzo(ghi)perylene	276	---	---	---	0.18	3.6423	0.04456	---
Dibenz(ah or aj) anthracenes	278	---	---	---	---	---	---	---
Dibenzacridines	279	---	---	---	---	---	---	---
Coronene	300	---	---	---	---	---	---	---
Dibenzo(a,h)pyrene	302	---	---	---	---	---	---	---
Dibenzo(a,i)pyrene	302	---	---	---	---	---	---	---
TOTAL		52.82	829.16	10.141	40.04	809.66	9.891	23.5

* Includes dimethyl- and ethyl-chrysenes, benzophenanthrenes, and benzanthracenes.

TABLE 8-12

COAL PREHEATER SAMPLES

POM Analysis

Test No. 8
Description: POM #8
Process Conditions: 109/271
Date: 7/29/78

Species	mw	INLET mg/m^3	INLET g/hr	INLET g/M ton	OUTLET mg/m^3	OUTLET g/hr	OUTLET g/M ton	%
Naphthalene	128	96	2676.2	24.578	31	671.77	6.1444	67.7
Fluorene	166	11	306.63	2.8125	4	86.68	0.7943	63.6
Anthracene/Phenanthrene	178	35	975.67	8.9419	15	325.00	2.9823	57.1
Fluoranthene	202	4.9	136.58	1.2539	1.7	36.83	0.3382	65.3
Pyrene	202	4.3	119.84	1.099	1.5	32.500	0.2982	65.1
Benz(a)anthracene/(c)phenanthrene	229	2.7	75.25	0.6894	1.1	23.813	0.2188	59.3
Chrysene/Triphenylene	228	4.3	119.84	1.099	1.7	36.832	0.3381	60.5
Benzo(b or k)fluoranthene	252	2.9	80.83	0.7443	1.6	34.654	0.3182	44.8
Benzo(j)fluoranthene	252	0.33	9.199	0.08442	0.09	1.9504	0.01789	72.7
Benzo(e)pyrene	252	2.2	61.33	0.5645	0.87	18.85	0.17299	60.5
Benzo(a)pyrene	252	1.3	36.24	0.3327	0.62	13.426	0.12329	52.3
Cholanthrene	254	---	---	---	---	---	---	---
Dimethyl benzanthracene isomers*	256	3.7	103.15	0.9441	3.8	82.327	0.75432	---
Dibenzo(c,g)carbazole	267	---	---	---	---	---	---	---
3-Methylcholanthrene	268	---	---	---	0.15	3.2522	0.02982	---
Indeno(1,2,3-cd)pyrene	276	0.14	3.9087	0.03582	0.09	1.9504	0.1789	35.7
Benzo(ghi)perylene	276	0.45	12.542	0.1149	0.18	3.9009	0.03582	60.0
Dibenz(ah or aj) anthracenes	278	---	---	---	0.07	1.4968	0.01394	---
Dibenzacridines	279	---	---	---	---	---	---	---
Coronene	300	---	---	---	---	---	---	---
Dibenzo(a,h)pyrene	302	---	---	---	---	---	---	---
Dibenzo(a,i)pyrene	302	---	---	---	---	---	---	---
TOTAL		164.22	4717.3	43.31	63.47	1375.28	12.639	62.5

* Includes dimethyl- and ethyl-chrysenes, benzophenanthrenes, and benzanthracenes.

TABLE 8-13

COAL PREHEATER SAMPLES

POM Analysis

Test No. 9
Description: POM #9
Process Conditions: 29/260
Date: 7/31/78

Species	mw	INLET mg/m^3	INLET g/hr	INLET g/M ton	OUTLET mg/m^3	OUTLET g/hr	OUTLET g/M ton	%
Naphthalene	128				52	586.99	19.48	
Fluorene	166				5.8	63.05	2.173	
Anthracene/Phenanthrene	178				21	228.61	7.893	
Fluoranthene	202				9.91	9.93	0.3412	
Pyrene	202				0.82	8.94	0.3077	
Benz(a)anthracene/(c)ph nanthrene	228				0.084	0.916	0.03147	
Chrysene/Triphenylene	228				0.22	2.399	0.08243	
Benzo(b or k)fluoranthene	252				0.047	0.513	0.01758	
Benzo(j)fluoranthene	252				---	---	---	---
Benzo(e)pyrene	252				0.091	0.9934	0.03412	
Benzo(a)pyrene	252				0.022	0.2399	0.00824	
Cholanthrene	254				---	---	---	---
Dimethyl benzanthracene isomers*	256				---	---	---	---
Dibenzo(c,g)carbazole	267				---	---	---	---
3-Methylcholanthrene	268				---	---	---	---
Indeno(1,2,3-cd)pyrene	276				---	---	---	---
Benzo(ghi)perylene	276				---	---	---	---
Dibenz(ah or aj) anthracenes	278				---	---	---	---
Dibenzacridines	279				---	---	---	---
Coronene	300				---	---	---	---
Dibenzo(a,h)pyrene	302				---	---	---	---
Dibenzo(a,i)pyrene	302				---	---	---	---
TOTAL					80.994	883.14	30.348	---

* Includes dimethyl- and ethyl-chrysenes, benzophenanthrenes, and benzanthracenes

TABLE 8-14

COAL PREHEATER SAMPLES

POM Analysis

Test No. 10
Description: POM #10
Process Conditions: 82/271
Date: 8/2/78 8/2/79

Species	me	INLET mg/m^3	INLET g/hr	INLET g/M ton	OUTLET mg/m^3	OUTLET g/hr	OUTLET g/M ton	η %
Naphthalene	128	18	391.85	4.796	23	325.46	3.982	---
Fluorene	166	2.5	54.43	0.6494	3.6	50.94	0.6234	---
Anthracene/Phenanthrene	178	17	370.08	4.531	8.6	121.70	1.489	46.4
Fluoranthene	202	1.2	26.13	0.3197	0.43	6.078	0.0744	64.2
Pyrene	202	1.2	26.13	0.3197	0.45	6.350	0.07793	62.5
Benz(a)anthracene/(c)phenanthrene	228	0.73	15.	0.1948	0.19	2.690	0.03292	74.0
Chrysene/Triphenylene	228	1.7	37.01	0.4531	0.47	6.668	0.08143	72.4
Benzo(b or k)fluoranthene	252	0.71	15.46	0.1893	0.26	3.679	0.04501	63.4
Benzo(j)fluoranthene	252	0.04	0.8709	0.0106	0.03	0.4246	0.005195	25.0
Benzo(e)pyrene	252	0.63	13.698	0.1678	0.07	0.9906	0.01214	88.9
Benzo(a)pyrene	252	0.24	5.216	0.06394	---	---	---	---
Cholanthrene	254	---	---	---	---	---	---	---
Dimethyl benzanthracene isomers*	256	1.7	37.008	0.4531	0.41	5.806	0.07094	75.9
Dibenzo(c,g)carbazole	267	---	---	---	---	---	---	---
3-Methylcholanthrene	268	---	---	---	---	---	---	---
Indeno(1,2,3-cd)pyrene	276	0.06	1.306	0.01599	---	---	---	---
Benzo(ghi)perylene	276	---	---	---	---	---	---	---
Dibenz(ah or aj) anthracenes	278	---	---	---	---	---	---	---
Dibenzacridines	279	---	---	---	---	---	---	---
Coronene	300	---	---	---	---	---	---	---
Dibenzo(a,h)pyrene	302	---	---	---	---	---	---	---
Dibenzo(a,i)pyrene	302	---	---	---	---	---	---	---
TOTAL		45.71	995.18	12.189	37.51	530.7	6.494	17.9

* Includes dimethyl- and ethyl-chrysenes, benzophenanthrenes, and benzanthracenes.

TABLE 8-15

COAL PREHEATER SAMPLES

POM Analysis

Test No. 11
Description: POM #11
Process Conditions: 82/260
Date: 8/3/78

Species	mw	INLET mg/m^3	INLET g/hr	INLET g/M ton	OUTLET mg/m^3	OUTLET g/hr	OUTLET g/M ton	η %
Naphthalene	128	18	192.32	2.348	11	172.14	2.108	38.9
Fluorene	166	2.3	24.58	0.300	2.6	40.69	0.498	---
Anthracene/Phenanthrene	178	12	128.23	1.569	9.5	148.69	1.818	20.8
Fluoranthene	202	1.1	11.748	0.1439	0.71	11.113	0.1359	35.5
Pyrene	202	0.97	10.342	0.1269	0.65	10.160	0.1244	33
Benz(a)anthracene/(c)phenanthrene	228	0.51	5.443	0.0664	0.37	5.792	0.0709	27.5
Chrysene/Triphenylene	228	1.2	12.837	0.1569	0.73	11.4259	0.1399	39.2
Benzo(b or k)fluoranthene	252	0.4	4.264	0.05245	0.35	0.06940	0.06694	12.5
Benzo(j)fluoranthene	252	---	---	---	0.02	0.003946	0.003847	---
Benzo(e)pyrene	252	0.35	3.738	0.04576	0.28	0.05534	0.05345	20
Benzo(a)pyrene	252	0.11	1.175	0.01439	0.13	0.02576	0.02498	---
Cholanthrene	254	---	---	---	---	---	---	---
Dimethyl benzanthracene isomers*	256	0.96	10.251	0.12539	0.88	0.1746	0.1683	8.3
Dibenzo(c,g)carbazole	267	---	---	---	---	---	---	---
3-Methylcholanthrene	268	---	---	---	---	---	---	---
Indeno(1,2,3-cd)pyrene	276	0.04	0.4273	0.005245	0.05	0.009934	0.009591	---
Benzo(ghi)perylene	276	---	---	---	---	---	---	---
Dibenz(ah or aj) anthracenes	278	---	---	---	---	---	---	---
Dibenzacridines	279	---	---	---	---	---	---	---
Coronene	300	---	---	---	---	---	---	---
Dibenzo(a,h)pyrene	302	---	---	---	---	---	---	---
Dibenzo(a,i)pyrene	302	---	---	---	---	---	---	---
TOTAL		37.94	405.37	4.9605	27.27	426.83	5.245	28.1

* Includes dimethyl- and ethyl-chrysenes, benzophenanthrenes, and benzanthracenes

TABLE 8-16

SCRUBBER WATER INLET-OUTLET ANALYSIS

Component	CONCENTRATION (mg/L)					
	Test No. 1		Test No. 2		Test No. 3	
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Naphthalene	0.27	0.05	0.28	0.01	0.03	0.05
Fluorene	0.02	---	0.07	0.01	0.01	0.01
Anthracene/ Phenanthrene	0.06	0.04	0.17	0.02	0.16	0.04
Fluoranthene	0.01	---	0.01	---	0.02	---
Pyrene	0.02	---	0.02	---	0.02	0.01
Benz(a)anthracene/(c)phenanthrene	---	---	---	---	0.01	---
Chrysene Triphenylene	---	---	---	---	0.02	---
Benzo(e)pyrene	---	---	---	---	0.01	---
Dimethyl Benzanthracene isomers	---	---	---	---	0.02	---
Totals	0.38	0.09	0.55	0.04	0.30	0.11

8.2.5 Selected vs. Total POM

Since the GC/MS Data System requires a great deal of data to acquire a narrow, specific, list of POM species, it is possible to estimate the relative weight of the POM's compared to the total aromatic fraction of the extracted sample.

The original mass spectral data are acquired over a mass scan range of mw 125-310. Integration of this entire mass range provides a measure of the total aromatic content. It is then possible to extract the abundance of only those species with 3 or more rings (m/e > 178) from this total as a measure of total POM. Finally, a summation of the selected mass POM profiles (178, 202, 228, etc) gives a measure of total selected POM.

Table 8-17 tabulates the results for three typical samples, #8 inlet before and after LC and #8 outlet after LC. These results may be summerized by two statements:

1. The specific POMs of interest represent 3-10% of the sample.
2. The outlet sample has reduced amounts of the lighter species (that is, 3 ring and higher POMs represent 50% of the inlet samples compared to 90% of the outlet sample).

The percentage of the aromatic fraction of each sample represented by the specific POMs can also be estimated from the gravimetric analysis data. Table 8-18 shows that these values range from 3 to 14% for all the stack

samples (except No. 9 Outlet sample which is unexplainably high), and less than 1% for the water samples from test No. 3. Since the aromatic fraction represents about half of the total extract for most of these samples, the specific POMs analyzed by GC/MS represent 2-7% of the total sample. See Table 8-19.

TABLE 8-17

Comparison of 3-Ring and Higher POMs to Total Sample Extract

	8 Inlet w/o LC	8 Inlet w LC	8 Outlet w LC
Ratio of ion areas 178 thru 310 to total ion area	0.54	0.53	0.94
Ratio of area for sum of the ions of interest to the total ion area	0.06	0.10	0.03

TABLE 8-18

ANALYSIS OF AROMATIC FRACTIONS (mg/m^3)
OF COAL PREHEATER SAMPLES

Sample No.	GRAV	POM	% POM/GRAV
1, Inlet	394	27	6.9
1, Outlet	154	22	14
2, Inlet	359	22	6.1
2, Outlet	93	3.2	3.4
2B, Outlet	146	18	12
3, Inlet	1450	67	4.6
3, Outlet	323	19	5.9
4, Inlet	1230	150	12
4, Outlet	549	61	11
5, Inlet	977	69	7.1
5, Outlet	1410	104	7.4
6, Inlet	1610	72	4.5
6, Outlet	1190	32	2.7
7, Inlet	1310	53	4.1
7, Outlet	1130	40	3.5
8, Inlet	1370	170	12
8, Outlet	1040	64	6.1
9, Outlet	1961	81	41
10, Inlet	770	45	5.8
10, Outlet	371	38	10
11, Inlet	593	37	6.2
11, Outlet	269	27	10
H_2O, 3 Inlet	38	.3	.9
H_2O, 3 Outlet	22	.12	.5

TABLE 8-19

GRAVIMETRIC ANALYSIS OF COAL PREHEATER SAMPLES

Sample No.	Aromatic Fractions (mg/m^3)	Total (mg/m^3)	Aromatic Total (%)
1, Inlet	394	668	59
1, Outlet	154	603	26
2A, Inlet	359	807	44
2A, Outlet	93	175	53
2B, Outlet	146	439	33
3, Inlet	1450	2580	56
3, Outlet	323	807	40
4, Inlet	1230	2680	46
4, Outlet	549	1520	36
5, Inlet	977	2080	47
5, Outlet	1410	2740	51
6, Inlet	1610	3610	45
6, Outlet	1190	2730	44
7, Inlet	1310	1950	67
7, Outlet	1130	2040	55
8, Inlet	1370	2960	46
8, Outlet	1040	2340	44
9, Outlet	196	843	23
10, Inlet	770	2140	36
10, Outlet	371	1130	33
11, Inlet	593	1290	46
11, Outlet	269	840	32
H_2O, 3 Inlet	38	59	64
H_2O, 3 Outlet	22	92	24

8.2.6 Toxicity Level of Coal Preheater Emissions

One basis for estimating the toxicity level of the coal preheater emissions is to compare the concentrations of the various POM species found in the effluent stream to the corresponding Discharge Multimedia Environmental Goal (DMEG) levels. Table 8-20 lists the available DMEG values of interest. Using the Source Analysis Models (SAMS) developed by EPA a quality called "Discharge Severity" (DS) can be obtained for each pollutant species by taking the ratio of the pollutant concentration to the corresponding DMEG value for that species. Tables 8-21 and 8-22 summarize these values for all the air samples taken at the outlet of the scrubber and Table 8-23 summarizes the DS values for the three outlet water samples analyzed. In cases where two or more compounds of the same modecular weight are not resolved in the GC/MS analysis, the assumption is made for the worst case, i.e., assuming all the concentration is due to the species having the lowest DMEG value. For example, to get the Discharge Severity value for benz(a)anthracene/benz(c)phenanthrene, the concentration found is divided by the DMEG of benz(a)anthracene (45 $\mu g/m^3$ in air). Data thus obtained show that in most of the air samples, the following species exceed the DMEG level: phenanthrene, benz(a) anthracene, benzo(a)pyrene, 7,12-dimethyl benz(a)-anthracene, and 3-methyl cholanthrene when present. None of the species found in the water samples exceed their DMEG values.

TABLE 8-20

POM DMEG Values Based on Health Effects

Species	m/e	Air, $\mu g/m^3$	Water, $\mu g/L$
Naphthalene	128	5×10^4	7.5×10^5
Fluorene	166	*	
Anthracene	178	5.6×10^4	8.4×10^5
Phenanthrene	178	1.6×10^3	2.4×10^4
Fluoranthene	202	9×10^4	1.4×10^6
Pyrene	202	2.3×10^5	3.5×10^6
Benz(a)anthracene	228	45	670
Benzo(c)phenanthrene	228	2.7×10^4	4.1×10^5
Chrysene	228	2.2×10^3	3.3×10^4
Triphenylene	228		
Benzo(b)fluoranthene	252	900	1.3×10^4
Benzo(k)fluoranthene	252	1.6×10^3	2.5×10^4
Benzo(j)fluoranthene	252	6.5×10^3	9.8×10^4
Benzo(e)pyrene	252	3×10^3	4.6×10^4
Benzo(a)pyrene	252	0.02	0.3
Cholanthrene	254		
12-Dimethyl benz(a)anthracene	256	0.26	3.9
Dibenzo(c,g)carbazole	267		
3-Methylcholanthrene	268	3.8	56
Indeno(1,2,3-cd)pyrene	276	1.6×10^3	2.4×10^4
Benzo(ghi)perylene	276		
Dibenz(ah)anthracene	278	0.093	1.4
Dibenz(a,h)acridine	279	220	3.4×10^3
Dibenz(a,j)acridine	279	250	3.7×10^3
Coronene	300		
Dibenzo(a,h)pyrene	302	3.7×10^3	5.6×10^4
Dibenzo(a,i)pyrene	302	43	650

* All blanks are data not available

TABLE 8-21

DISCHARGE SEVERITY CALCULATED FOR POM IN COAL PREHEATER SAMPLES, OUTLET

Discharge Severity (DS)

Species	m/e	Test Number					
		1	2	3	4	5	6
Naphthalene	128	0.3	0.04	0.3	0.9	1	0.3
Fluorene	166	-	-	-	-	-	-
Anthracene/Phenanthrene	178	3[a]	0.4[a]	2[a]	5[a]	10[a]	5[a]
Fluoranthene	202	0.004	0.0005	0.002	0.01	0.02	0.009
Pyrene	202	0.002	0.0002	0.0008	0.004	0.006	0.004
Benz(a)anthracene/(c)phenanthrene	228	2[b]	0.7[b]	4[b]	10[b]	30[b]	10[b]
Chrysene/Triphenylene	228	0.1[c]	0.04[c]	0.3[c]	0.5[c]	1[c]	0.9[c]
Benzo(b or k)fluoranthene	252	0.08[d]	0.03[d]		0.5[d]	1[d]	1[d]
Benzo(j)fluoranthene	252	**					
Benzo(e)pyrene	252	0.03	0.008	0.02	0.1	0.2	0.3
Benzo(a)pyrene	252	3000	500		9000		18500
Cholanthrene	254						
Dimethyl benzanthracene isomers*	256	500[e]	300[e]		9000[e]	10000[e]	10000[e]
Dibenzo(c,g)carbazole	267						
3-Methylcholanthrene	268						
Indeno(1,2,3-cd)pyrene	276						
Benzo(ghi)perylene	276		-				-
Dibenz(ah or aj) anthracenes	278						
Dibenzacridines	279						
Coronene	300						
Dibenzo(a,h)pyrene	302						
Dibenzo(a,i)pyrene	302						

* Includes dimethyl- and ethyl-chrysenes, benzo-phenanthrenes, benzathracenes.

** All blanks are items below detection limit.

\- DMEG values are not available.

a. Based on DMEG of Phenanthrene.

b. Based on DMEG of Benz(a)anthracene.

c. Based on DMEG of Chrysene.

d. Based on DMEG of Benzo(b) fluoranthrene.

e. Based on DMEG of 7,12-Dimethyl benz(a) anthracene.

TABLE 8-22

DISCHARGE SEVERITY CALCULATED FOR POM IN COAL PREHEATER SAMPLES, OUTLET

Discharge Severity (DS)

Species	m/e	Test Number					
		7	8	9	10	11	2B
Naphthalene	128	0.3	0.6	1	0.5	0.2	0.3
Fluorene	166	-	-	-	-	-	-
Anthracene/Phenanthrene	178	8[a]	9[a]	10[a]	5[a]	6[a]	2[a]
Fluoranthene	202	0.007	0.02	0.01	0.005	0.008	0.003
Pyrene	202	0.003	0.007	0.004	0.002	0.003	0.0006
Benz(a)anthracene/(c)phenanthrene	228	20[b]	30[b]	2[b]	4[b]	8[b]	6[b]
Chrysene/Triphenylene	228	0.8[c]	0.9[c]	0.1[c]	0.3[c]	0.4[c]	0.2[c]
Benzo(b or k)fluoranthene	252	1[d]	2[d]	0.05[d]	0.3[d]	0.4[d]	
Benzo(j)fluoranthene	252	0.01	0.01		0.004	0.004	
Benzo(e)pyrene	252	0.3	0.3	0.03	0.02	0.09	0.04
Benzo(a)pyrene	252	20000	30000	1000		7000	4000
Cholanthrene	254						
Dimethyl benzanthracene isomers*	256	7000[e]	10000[e]		2000[e]	3000[e]	
Dibenzo(c,g)carbazole	267						
3-Methylcholanthrene	268	30	40				
Indeno(1,2,3-cd)pyrene	276		0.06				
Benzo(ghi)perylene	276	-	-			-	
Dibenz(ah or aj) anthracenes	278		800[f]				
Dibenzacridines	279						
Coronene	300						
Dibenzo(a,h)pyrene	302						
Dibenzo(a,i)pyrene	302						

* Includes dimethyl- and ethyl-chrysenes, benzo phenanthrenes benzathracenes.

** All blanks are items below detection limit.

\- DMEG values are not available.

a. Based on DMEG of Phenanthrene.

b. Based on DMEG of Benz(a)anthracene.

c. Based on DMEG of Chrysene.

d. Based on DMEG of Benzo(b)fluoranthene.

e. Based on DMEG of 7,12-Dimethyl benz(a) anthracene.

f. Based on DMEG of Dibenz(ah)anthracene.

TABLE 8-23

DISCHARGE SEVERITY CALCULATED FOR POM IN COAL PREHEATER SAMPLES, OUTLET

Species	m/e	Discharge Severity		
		Test Number		
		1, H_2O	2, H_2O	3, H_2O
Naphthalene	128	7×10^{-5}	2×10^{-5}	7×10^{-5}
Fluorene	166		-	-
Anthracene/Phenanthrene	178	2×10^{-3}	9×10^{-4}	2×10^{-3}
Fluoranthene	202			3×10^{-6}
Pyrene	202	1×10^{-6}		2×10^{-6}
Benz(a)anthracene/(c)phenanthrene	228			
Chrysene/Triphenylene	228			
Benzo(b or k)fluoranthene	252			
Benzo(j)fluoranthene	252			
Benzo(e)pyrene	252			
Benzo(a)pyrene	252			
Cholanthrene	254			
Dimethyl benzanthracene isomers*	256			
Dibenzo(c,g)carbazole	267			
3-Methylcholanthrene	268			
Indeno(1,2,3-cd)pyrene	276			
Benzo(ghi)perylene	276			
Dibenz(ah or aj) anthracenes	278			
Dibenzacridines	279			
Coronene	300			
Dibenzo(a,h)pyrene	302			
Dibenzo(a,i)pyrene	302			

* Includes dimethy- and ethyl-chrysenes, benzophenanthrenes, and benzanthracenes.

** All blanks are items below detection limit.

\- DMEG values are not available.

8.3 EPA-5 Train Test Results

Particulate emissions analyzed in accordance with EPA Method 5 are summerized in Table 8-24. Results are presented in terms of chloroform soluble and non-chloroform soluble emissions. On the basis of one test, the total scrubber inlet concentration (chloroform and non-chloroform soluble particulate in the front and back half catches, but not including the silica gel) was 9014.7 mg/Nm^3. Outlet concentrations ranged from 951.8 to 1635.9 mg/Nm^3.

TABLE 8-24

Chloroform Suluble & Non-Chloroform Soluble Particulates

A. Non-Chloroform Soluble Particulate

Test No.	Location	Nozzle, Probe, Front Half Filter Holder		Filter		Back Half Filter Holder, Impinger Lines, Impingers, Impinger Solutions		Silica Gel		Total		
		mg/Nm^3	%WT.	mg/Nm^3	%WT.	mg/Nm^3	%WT.	mg/Nm^3	%WT.	mg/Nm^3	g/M-Ton	%WT.
1	Outlet	90.6	14.2	228.8	36.4	311.2	49.2	-	-	630.6	139.9	100
2	Inlet	922.1	11.2	6763.3	82.0	562.8	6.8	-	-	8248.2	1574.0	100
2	Outlet	59.5	7.2	572.0	69.4	192.2	23.4	-	-	823.7	127.9	100
3	Outlet	75.5	13.1	391.2	68.1	107.2	18.8	-	-	573.9	132.0	100

B. Chloroform Soluble Particulate

Test No.	Location	Nozzle, Probe, Front Half Filter Holder		Filter		Back Half Filter Holder, Impinger Lines, Impingers, Impinger Solutions		Silica Gel		Total		
		mg/Nm^3	%WT.	mg/Nm^3	%WT.	mg/Nm^3	%WT.	mg/Nm^3	%WT.	mg/Nm^3	g/M-Ton	%WT.
1	Outlet	9.8	1.3	100.0	12.5	213.0	26.7	475.4	59.5	798.2	178.0	100
2	Inlet	93.4	9.2	416.9	41.0	266.6	26.2	239.6	23.6	1016.5	194.0	100
2	Outlet	7.5	1.1	402.0	58.2	197.2	28.6	83.5	12.1	690.0	107.5	100
3	Outlet	2.5	0.2	140.9	11.8	918.4	76.9	132.9	11.1	1194.7	274.5	100

C. Total Particulate (Chloroform Soluble + Non-Chloroform Soluble)

Test No.	Location	EPA-5		PA-DER	
		mg/Nm^3	g/M-Ton	mg/Nm^3	g/M-Ton
1	Outlet	429.2	95.5	953.4	212.2
2	Inlet	8195.7	1563.9	9025.1	1722.3
2	Outlet	1041.0	161.6	1430.4	222.2
3	Outlet	610.1	140.3	1635.7	376.1

8.4 Results of Benzine Soluble Organic Analysis

The particulate loadings and benzine soluble organic residue loadings are summarized in Table 8-25 for the six BSO Tests.

Particulate loadings at the scrubber inlet range from 1600.5 to 9205.0 mg/Nm^3. Outlet loadings range from 199.3 to 1332.4 mg/Nm^3.

Benzine soluble organic concentration at the scrubber inlet ranged from 1157.3 to 2741.4 mg/Nm^3. Concentration at the outlet ranged from 783.3 to 1930.3 mg/Nm^3.

Individual test results are given in Tables 8-26 through 8-31 which also provide concentrations by sampling train component for both particulates and benzine soluble organics.

TABLE 8-25

SUMMARY OF BENZENE SOLUBLE TESTS

These tests were conducted for determination of benzene soluble residue in the inlet and outlet to the coal preheater scrubber. Particulate weight is also reported.

Benzene Soluble Residue

Test No.	Process Conditions*	mg/m^3	g/hr	g/M tons of Coal
1 inlet	82/271	1157.3	35489	435
1 outlet	82/271	783.3	14900	186.3
2 inlet	109/271	2741.4	106340	970
2 outlet	109/271	1930.3	55460	533.7
3 inlet	55/288	1279.4	24971	457.7
3 outlet	55/288	1343.7	21763	397.2

Particulate Residue**

Test No.	Process Conditions*	mg/m^3	g/hr	g/M tons of coal
1 inlet	82/271	9205.0	255371	3143
1 outlet	82/271	199.3	3787.5	45.5
2 inlet	109/271	5524.8	201838	1882.5
2 outlet	109/271	1332.4	39862	365.9
3 inlet	55/288	1605.5	312355	5739.8
3 outlet	55/288	227.8	3687	66

* Coal feed rate in (M-Tons per hour)/(temperature, ^{o}C)

** Does not include weight of benzene soluble residue.

TABLE 8-26

Benzene Soluble Test No. 1 Inlet

Process Conditions: coal feed rate = 90 tons/hr
temperature = 520°F

Benzene Soluble Residue

Sampling Train Component	mg/m^3	g/hr	g/M tons of coal
1. Front half Benzene wash	820.0	22748	280.0
2. Front half Acetone wash	47.6	1320	16.0
3. Filter	133.1	3692	45.0
4. Adsorber	135.4	3756	46.0
5. Back half Benzene wash	119.0	3302	40.0
6. Back half Acetone wash	24.2	671	8.0
Total	1157.3	35489	435.0

Particulate Residue

Sampling Train Component	mg/m^3	g/hr	g/M tons of coal
1. Front half Benzene wash	5590.0	155082	1898.0
2. Front half Acetone wash	80.5	2236	27.0
3. Filter	3497.0	97023	1199.0
4. Adsorber	0.0	0	0.0
5. Back half Benzene wash	1.89	54	6.5
6. Back half Acetone wash	35.5	984	12.0
Total	9204.9	255371	3143.0

TABLE 8-27

Benzene Soluble Test No. 1 Outlet

Process Conditions: coal feed rate = 90 tons per hour
temperature = 520°F

Benzene Soluble Residue

Sampling Train Component	mg/m^3	g/hr	g/M tons of coal
1. Front half Benzene wash	26.7	508	5.99
2. Front half Acetone wash	12.9	245	3.00
3. Filter	40.9	780	9.49
4. Adsorber	271.	5171	64.94
5. Back half Benzene wash	402.2	7648	94.41
6. Back half Acetone wash	28.8	549	6.49
Total	783.3	14900	186.33

Particulate Residue

Sampling Train Component	mg/m^3	g/hr	g/M tons of coal
1. Front half Benzene wash	21.1	399.2	4.90
2. Front half Acetone wash	21.4	408.2	5.00
3. Filter	144.8	2753.3	33.50
4. Adsorber	0.0	0.0	0.0
5. Back half Benzene wash	10.6	27.2	0.33
6. Back half Acetone wash	1.4	199.6	1.85
Total	199.3	3787.5	45.55

TABLE 8-28

Benzene Soluble Test No. 2 Inlet

Process Conditions: coal feed rate = 120 tons/hr
temperature = 520°F

Benzene Soluble Residue

Sampling Train Component	mg/m^3	g/hr	g/M tons of coal
1. Front half Benzene wash	2097.0	76611	699.0
2. Front half Acetone wash	18.9	694	6.0
3. Filter	177.3	12664	115.0
4. Adsorber	103.9	3797	34.5
5. Back half Benzene wash	312.6	11417	105.0
6. Back half Acetone wash	31.6	1157	10.5
Total	2741.4	106340	970.0

Particulate Residue

Sampling Train Component	mg/m^3	g/hr	g/M tons of coal
1. Front half Benzene wash	2631.0	46116	899.0
2. Front half Acetone wash	89.4	3270	30.0
3. Filter	2791.0	101967	949.0
4. Adsorber	0.0	0	0.0
5. Back half Benzene wash	9.4	340	3.15
6. Back half Acetone wash	3.9	145	1.35
Total	5524.7	201838	1882.5

TABLE 8-29

Benzene Soluble Test No. 2 Outlet

Process Conditions: coal feed rate = 120 tons/hr
temperature = 520°F

Benzene Soluble Residue

Sampling Train Component	mg/m^3	g/hr	g/M tons of coal
1. Front half Benzene wash	197.6	5910	55.0
2. Front half Acetone wash	11.5	345	3.15
3. Filter	831.8	24875	230.0
4. Adsorber	322.4	9643	90.0
5. Back half Benzene wash	565.0	14628	155.0
6. Back half Acetone wash	1.9	59	0.55
Total	1930.3	55460	533.7

Particulate Residue

Sampling Train Component	mg/m^3	g/hr	g/M tons of coal
1. Front half Benzene wash	128.7	3851	35.0
2. Front half Acetone wash	21.5	644	6.0
3. Filter	1145.0	34255	315.0
4. Adsorber	0.0	0	0.0
5. Back half Benzene wash	66.1	200	1.9
6. Back half Acetone wash	30.5	912	8.0
Total	1332.4	39862	365.9

TABLE 8-30

Benzene Soluble Test No. 3 Inlet

Process Conditions: coal feed rate = 60 tons/hr
temperature = 550°F

Benzene Soluble Residue

Sampling Train Component	mg/m^3	g/hr	g/M tons of coal
1. Front half Benzene wash	279.7	5457	100.0
2. Front half Acetone wash	36.2	708	13.0
3. Filter	277.7	5420	100.0
4. Adsorber	187.9	3570	65.0
5. Back half Benzene wash	489.7	9557	175.0
6. Back half Acetone wash	13.2	259	4.7
Total	1279.4	24971	457.7

Particulate Residue

Sampling Train Component	mg/m^3	g/hr	g/M tons of coal
1. Front half Benzene wash	3176.0	62006	1149.0
2. Front half Acetone wash	207.4	4050	75.0
3. Filter	12420.0	242353	4446.0
4. Adsorber	0.0	0	0.0
5. Back half Benzene wash	189.4	3697	65.0
6. Back half Acetone wash	12.7	249	4.8
Total	16005.5	312355	5739.8

TABLE 8-31

Benzene Soluble Test No. 3 Outlet

Process Conditions: coal feed rate = 60 tons/hr
temperature = 550°F

Benzene Soluble Residue

Sampling Train Component	mg/m^3	g/hr	g/M tons of coal
1. Front half Benzene wash	7.5	122	2.2
2. Front half Acetone wash	21.0	340	6.0
3. Filter	72.1	1170	21.0
4. Adsorber	155.3	2513	46.0
5. Back half Benzene wash	143.1	3318	42.0
6. Back half Acetone wash	944.7	15300	280.0
Total	1343.7	21763	397.2

Particulate Residue

Sampling Train Component	mg/m^3	g/hr	g/M tons of coal
1. Front half Benzene wash	66.2	1070	19.0
2. Front half Acetone wash	26.3	426	7.5
3. Filter	86.3	1397	25.0
4. Adsorber	0.0	0	0.0
5. Back half Benzene wash	18.1	295	5.5
6. Back half Acetone wash	30.2	499	9.0
Total	227.7	3687	66.0

8.5 Results EPA Level 1 Organic Analysis

The Level 1 Organic Analysis results for the two stack samples, two water samples, and the blanks are shown in Tables 8-32 through 8-37. The organic species found in each sample extract were classified into compound categories based on the LC, IR, and LRMS data. The concentration of each category was estimated using the method described in the EPA Level 1 procedure manual. These data are further summarized in Table 8-38. Aliphatic hydrocarbons, fused aromatics, phenols, and esters were found to be the major components for both inlet and outlet stack samples, with lower concentrations for the inlet sample. Aliphatic hydrocarbons, carbazoles, and phenols were found in the water samples. The alkyl benzenes and dibutyl phthalate which were found in the outlet water sample but not in the inlet water sample could be attributed to contaminants in the sample.

TABLE 8-32

Organic Extract Summary

Sample 2A Inlet, Stack Sample

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/m^3	188	520	87	23	33	213	40	1100
TCO, mg	111	305	34	7.7	12	43	13	530
GRAV, mg	130	360	78	22	30	230	38	890

Category	Int/mg/m^3							
Aliphatic Hydrocarbons	10/188							188
Fused Aromatics, <216 m/e		100/260	100/73	100/5.6	10/2.4			341
Fused Aromatics, >216 m/e		100/260	10/7.3	100/5.6	10/2.4			275
Heterocyclic N Compounds				100/5.6	10/2.4	10/9.7	10/1.9	20
Esters				100/5.6	100/24	100/97	100/19	146
Phenols						100/97	100/19	116
Unclassified			10/7.3	10/0.6	10/2.4	10/9.7	1/0.2	20

TABLE 8-33

Organic Extract Summary

Sample 2A Outlet, Stack Sample

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/m^3	63	94	35	5.8	5.8	7.7	15	230
TCO, mg	45	49	1.6	2.1	1.1	2.9	7.2	109
GRAV, mg	37	73	43	5.5	6.5	7.3	12	184

Category	Int/mg/m^3							
Aliphatic Hydrocarbons	100/57		100/17					74
Fused Aromatics, m/e <216		100/31	100/17	10/0.4				7.7
Fused Aromatics, m/e >216		100/31	100/1.7	10/0.4				48
Heterocyclic N Compounds		100/31		10/0.4				33
Esters				100/4.4	100/5.7	100/7.7	100/15	31
Unclassified	10/5.7			1/0.1	1/0.6		1/1.5	33

TABLE 8-34

Organic Extract Summary

Sample 2 Inlet, Water Sample

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/L	76	22	3.4	4.4	5.2	26	13	150
TCO, mg	8.4	4.1	0.9	1.2	1.3	1.3	3.6	21
GRAV, mg	30	6.7	0.8	1.0	1.3	12	3.1	55

Category	Int/mg/L							
Aliphatic Hydrocarbons	100/69							69
Fused Aromatics, m/e <216		100/11	100/1.1	100/1.5				13
Fused Aromatics, m/e >216		100/11	100/1.1	100/1.5				13
Heterocyclic N Compounds			100/1.1	100/1.5	100/1	100/8.4	100/4.2	16
Phenols					100/1	100/8.4	100/4.2	14
Esters					100/1			1.0
Ketones and Aldehydes					100/1	100/8.4	100/4.2	14
Unclassified	10/6.9	10/1	10/0.1		100/1	10/0.8	10/0.4	10

TABLE 8-35

Organic Extract Summary

Sample 2 Outlet, Water Sample

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/L	40	24	28	42	4.6	36	9.2	184
TCO, mg	1.2	0.4	0.7	0.7	1.0	2.1	1.3	7.3
GRAV, mg	19	12	13	20	1.3	16	3.3	85

Category	Int/mg/L							
Aliphatic Hydrocarbons	100/36	10/1.1	100/13	10/3.5				54
Aromatic Hydrocarbons		100/11	100/13	10/3.5				28
Heterocyclic N Compounds					10/0.5*	100/12	100/3	15
Ketones					100/2.3*	100/12		14
Phenols					10/0.5*	100/12	100/3	15
Esters		100/11	10/1.3	100/35	10/0.5*			48
Carboxylic Acids							100/3	3.0
Unclassified	10/3.6					10/1.2	10/0.3	5.1

*Estimated from LC and IR data, with LRMS data of adjacent fractions

TABLE 8-36

Organic Extract Summary

Sample Stack Blank

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/m^3	28	2.6	22	2.6	3.2	8.8	11	78
TCO, mg	ND	0.3	0.6	0.8	0.8	3.6	3.9	10
GRAV, mg	14	1.0	10	0.5	0.8	0.8	1.8	29

Category	Int/mg/m^3							
Aliphatic Hydrocarbons		10/0.3*	10/1.0					1.3
Aromatic Hydrocarbons			100/10					10
Esters			100/10	100/1.3*	1/3.2	100/4.4*	1/11	30
Unclassified	10/28							28

*Estimated from LC and IR data, with LRMS data of adjacent fractions

TABLE 8-37

Organic Extract Summary

Sample Water Blank

	LC1	LC2	LC3	LC4	LC5	LC6	LC7	Σ
Total Organics, mg/L	40	3.0	3.0	2.6	2.6	1.6	3.0	56
TCO, mg	2.7	0.7	0.2	0.8	0.5	0.8	1.0	
GRAV, mg	17	0.8	1.3	0.5	0.8	ND	0.5	

Category	Int/mg/L							
Aliphatic Hydrocarbons	100/36	10/0.3*						36
Esters			10/0.3**	10/0.3**	10/0.3*	1/1.6	10/0.3*	2.8
Unclassified	10/4.0							4.0

*Estimated from LC and IR Data, with LRMS data of adjacent fractions

**Estimated from LC and IR Data.

TABLE 8-38

SUMMARY OF EPA LEVEL 1 ORGANIC ANALYSIS

Compound Categories	Stack Samples (mg/m^3)		Water Samples (mg/L)	
	2A Inlet	2A Outlet	2 Inlet	2 Outlet
Aliphatic Hydrocarbons	190	74	69	54
Aromatic Hydrocarbons				28
Fused Aromatics, <m/e 216	340	8	13	
Fused Aromatics, >m/e 216	280	48	13	
Heterocyclic N Compounds	20	33	16	15
Aldehydes & Ketones			14	14
Alcohols, Phenols	120		14	15
Esters	150	31	1	48
Carboxylic Acids				3

8.6 Benzene and Total Hydrocarbons in Stack Gas Grab Samples

The results of the GC analysis on the grab samples are given in Table 8-39. Both benzine and total hydrocarbons (measured as methane) appear to significantly increase across the scrubber.

TABLE 8-39

Benzine and Total Hydrocarbons in Grab Samples

Test Date	Process* Conditions	Benzene (PPM) Inlet	Benzene (PPM) Outlet	Total Hydrocarbons** Inlet	Total Hydrocarbons** Outlet
7/26/78	108.4/287.8	42.0	57.1	708.9	266.5
7/27/78	108.0/287.8	0.8***	12.1	249.5	1942.1
7/28/78	81.6/287.8	0.8	3.7	353.6	242.6
7/29/78	108.9/271.1	8.1	8.1	195.4	1605.0
7/30/78	54.4/287.8	0.8	15.1	112.1	2718.3
7/31/78	29.0/260.0	no sample	9.9	no sample	732.2
8/2/78	81.6/271.1	0.8	1.8	317.7	2190.2
8/3/78	81.6/260.0	0.8	23.0	26.6	399.4

* (Coal feed rate, M-Ton/Hr)/(Temperature, ^{o}C)
** Total Hydrocarbons determined as methane
*** The detection limit for benzene was 0.8 ppm.

8.7 Benzene Content in Water Grab Samples

No benzene was detected in the six water samples (Test 1, 2 and 3, inlet and outlet) when they were analyzed on a Porapak Q column with a Varian 2700 FID GC. The detection limit was 5 ppm. It is possible that trace amounts of benzene originally present in the samples were lost before the samples were analyzed.

8.8 Sulfur in Impinger Catches

The results of the sulfer analysis conducted on the impinger catches of POM tests #1, inlet and outlet, are presented in Table 8-40.

TABLE 8-40

Sulfur in Impinger Catches

Process Conditions: coal feed rate = 54 Microns/Hr
temperature = 276.6 °C

Test Number	mg/m^3	g/hr	g/M ton of coal
POM Test 1 Inlet			
Impinger water	74.90	1251.9	22.979
Methylene Chloride wash	0.974	16.33	0.2997
Total	75.9	1270.05	23.479
POM Test 1 Outlet			
Impinger Water	9.440	113.85	2.098
Methylene Chloride wash	0.822	9.888	0.180
Total	10.300	123.83	2.298

8.9 Coal Analysis

All the coal samples were sieved through a 100 mesh screen and analyzed for moisture, volatile matter, ash, sulfur and carbon contents according to ASTM methods (D3173, 3174, 3175, 3177, and 3178). Table 8-41 shows the sieving and moisture analyses results. For most of the coal samples, the fraction smaller than 100 mesh was found to be 10% for the Inlst samples and 20% for the Outlet samples. The moisture contents for all samples were Ca 1%. The results of volatile, ash, sulfur, and carbon analyses are summarized in Tables 8.42 and 8.43. Slightly higher ash contents were observed for the Inlet samples than the corresponding Outlet samples. No substantial differences in volatile, carbon, hydrogen, and sulfur contents were observed between the Inlet and Outlet samples.

The coal samples from Test No. 2 Inlet and Outlet were also analyzed for trace elements. The results are given in Tables 8-44 through 8-47. A summary table with the elements over 5 mg/kg concentration for the four samples is also presented (Table 8-48). All the coal samples were also examined by stereo microscope at magnifications from 7 to 30 times. Each sample was subsequently documented with a photomacrograph taken at 6X magnification. The general observations are as follows for the "inlet" or "outlet" samples:

1. Most of the inlet samples exist as coarser and non-uniform particle sizes.

2. Most of the outlet samples exist as smaller, more uniform sizes.
3. The inlet samples which were furnished in a can exhibit an acidic activity which corroded the interior of the can. Two inlet samples were packaged in glass where this corrosion was precluded.
4. The outlet samples did not corrod the interior of the can indicating the absence of acidity.
5. Many of the outlet samples have an oily odor similar to kerosene. This odor is not detected in any of the inlet samples.
6. All samples appear to be coal with almost no extraneous matter.
7. The particles are all irregular in shape.
8. There appears to be two basic forms of coal fragment. One exhibits smooth, glassy fracture faces while the other form has a dull matte surface presumably from a fine-grained microstructure.

The following comments and observations are pertinent to each of the specific coal samples examined by microscopy:

Sample No.	Observations
1 Inlet	Dull, brown-black color for most of material. There are a few shiney, highly-reflective surfaces which appear blacker than the rest of the material. No extraneous material noted. Some moisture is present, but which dries rapidly. Particle size range 2-3 mm and smaller.

1 Outlet	Sample appears blacker than #1 inlet, possibly because of more broken particles with shiney black surfaces apparent. Noted one small stone (silicate mineral). The fines on this sample tend to be aggregated, whereas No. 1 inlet tended to be dispersed.
2 Inlet	Similar size range. Probably more of the larger particles 2-5 mm size. Smaller sizes tend to aggregate. No extraneous matter noted.
2 Outlet	Sizes of particles up to approximately 5 mm. Smaller particles do not tend to aggregate. No extraneous matter noted.
3 Inlet	Sample is in quart can. Previous samples were in glass. Indicate that acidic moisture is present which reacted with metal can to produce rusty scale. Some of these rust fragments are apparent in the sample. Sample now appears dry--non-aggregated and brownish in color. There are more of larger particles greater than 5 mm.
3 Outlet	Noticeable kerosene odor upon opening the can. No corrosion noted on inner can wall. Finer particles (>5 mm). No obvious extraneous material.

4 Inlet	This sample consists of the dry, separated particulates. The color is brownish black. A sizable fraction consists of larger particle sizes >5 mm. Container wall is corroded from acid water attack. No extraneous matter noted in coal dust.
4 Outlet	Sample is slightly contaminated with corrosion (rust flakes) from inner walls of container. Particles are separate. Fairly large percentage of particles are larger than 2-3 mm.
5 Inlet	Sample is slightly contaminated with corrosion (rust flakes) from inner walls of container. Particles are separate. Fairly large percentage of particles are larger than 2-3 mm.
5 Outlet	Distinct kerosene odor noted upon opening the can. Particles tend to agglomerate. Note two different textures to larger particles; one is fine-grained while the other is more glassy. Most larger particles throughout these samples are flat plate-like.
(No 6 Inlet)	
6 Outlet	Very strong kerosene odor. Particles tend to aggregate. Particle size is largely below 3 mm. Color appearance is more jet black.

7 Inlet	Corrosion of can interior indicates probable acidic water content. Particles appear more of a gray black. Some aggregation is apparent. No extraneous material noted. Contents of can more irregular in particle size, several larger lumps 5-50 mm.
7 Outlet	Sample is more uniformly pulverized. Maximum size appears to be 3-5 mm. Particles appear dry-free flowing. Some of the larger (3-5 mm) particles are fine-grained in contrast to the usual glassy fragrants.
8 Inlet	Considerable corrosion to inside of can. Note that larger particles tend to aggreate. Some larger particles appear fine-grained instead of glassy. Some contamination noted due to corrosion products from side of can. Moisture present dries readily in room atmosphere.
8 Outlet	Faint oily odor noted. Can inside is not corroded. Fairly large amount of particles in 3-10 mm range. Some tendency for small particles to aggregate. No noticeable contamination.
9 Inlet	Interior of can is badly corroded. Particle size is non-uniform with larger particles up to 2-3 cm in diameter. Particles

	are non-aggregated. Some contamination from corrosion products from can. Some fine-grained particles in addition to the usual glassy type.
9 Outlet	No corrosion noted. Some aggregation of small particles. Faint oily odor noted. Sample is well pulverized. Few particles in 3-5 mm range.
10 Inlet	Some minor corrosion of can. Sample is well aggregated. Note 2 or 3 large particles in the 2 to 3 cm range. No extraneous material noted. Coal appears blacker due to whatever causes particles to aggregate.
10 Outlet	No corrosion noted. Sample is well pulverized. Largest particles less than 1 cm. No extraneous material. No aggregation apparent.
11 Inlet	Considerable corrosion to interior of can. Particle size of material is non-uniform. Many larger particles 1-3 cm. No aggregation. No extraneous matter.
12 Outlet	No corrosion noted. Particle size of material is in the small size range. Most under 5-10 mm. No aggregation noted. No extraneous material.

TABLE 8-41

SIZE AND MOISTURE ANALYSIS OF COAL SAMPLES
(Based on Sample Weights as Received at the Lab)

Sample No.	% <100 Mesh (A)	% >100 Mesh (B)	% Moisture	
Inlet			A	B
1	12.6	87.4	1.20	1.08
2	12.6	87.4	1.19	1.19
3	10.4	89.6	1.33	1.38
4	20.3	79.7	1.21	1.28
5	10.1	89.9	1.43	1.20
7	8.7	91.3	1.52	1.36
8	12.1	87.9	1.62	1.36
9	9.2	90.8	1.81	1.49
10	12.1	87.9	1.28	1.19
11	11.9	88.1	1.49	1.10
Outlet			A	B
1	28.6	71.4	1.24	1.11
2	17.1	82.9	1.03	0.79
3	18.1	81.9	2.55	1.12
4	16.2	83.8	0.65	1.03
5	15.0	85.0	1.44	1.30
6	12.4	87.6	6.74	5.23
7	18.2	81.8	0.82	1.00
8	15.3	84.7	0.82	1.04
9	27.3	72.7	0.82	0.87
10	19.2	80.8	0.84	1.21
11	23.2	76.8	0.83	0.92

TABLE 8-42

COAL ANALYSIS RESULTS

Inlet Samples, Based on Dry Coal Weight

Sample No.		Ash %	Volatile %	Carbon %	Hydrogen %	Oxygen + Undetermined %	Sulfur %
1	A	8.89	29.06	79.26	4.95	6.90	1.24
	B	7.11	31.69	80.15	5.07	7.67	1.13
2	A	8.94	28.54	78.94	4.79	7.33	1.23
	B	9.54	32.37	80.51	5.30	4.65	1.09
3	A	9.50	28.02	77.30	4.78	8.42	1.26
	B	8.22	31.87	78.77	5.00	8.01	1.11
4	A	9.66	28.70	77.76	4.80	7.78	1.23
	B	7.67	30.86	79.55	5.03	7.75	0.99
5	A	9.36	28.16	77.67	4.82	8.15	1.35
	B	7.54	32.15	80.08	5.08	7.30	1.11
7	A	8.41	29.18	78.40	4.87	8.32	1.18
	B	7.64	31.35	80.41	5.26	6.69	1.03
8	A	9.29	28.83	76.83	4.71	9.17	1.42
	B	8.54	32.72	77.85	5.06	8.55	1.21
9	A	9.61	27.95	77.18	4.76	8.45	1.39
	B	6.74	31.43	80.66	5.15	7.45	1.04
10	A	9.70	27.44	78.36	4.82	7.12	1.33
	B	6.42	32.66	80.30	5.15	8.13	1.17
11	A	8.13	28.07	79.42	4.85	7.60	1.38
	B	7.73	31.44	79.59	5.03	7.65	1.14
Avg.	A	9.15	28.40	78.11	4.82	7.92	1.30
	B	7.72	31.85	79.79	5.11	7.39	1.10

* A: Fraction of the coal samples smaller than 100 mesh.

B: Fraction of the coal samples greater than 100 mesh.

TABLE 8-43

COAL ANALYSIS RESULTS

Outlet Samples, Based on Dry Coal Weight

Sample No.		Ash %	Volatile %	Carbon %	Hydrogen %	Oxygen + Undetermined %	Sulfur %
1	A *	6.40	28.88	81.70	4.97	6.93	1.12
	B	6.25	32.22	80.77	5.16	7.82	1.15
2	A	6.18	28.20	81.75	4.97	7.10	1.13
	B	7.57	32.92	79.89	5.13	7.41	1.19
3	A	6.05	28.98	83.27	5.00	5.68	1.17
	B	6.80	32.68	79.91	5.09	8.20	1.24
4	A	6.66	27.79	80.39	4.87	8.08	0.92
	B	7.56	30.97	79.59	4.96	7.89	1.22
5	A	6.37	28.03	81.80	5.04	6.79	1.29
	B	6.37	32.54	79.92	5.07	8.64	1.16
6	A	8.35	29.63	83.85	4.95	2.85	1.24
	B	7.63	31.55	82.84	5.08	4.45	1.13
7	A	6.27	28.75	80.59	4.91	8.23	1.26
	B	6.96	31.90	79.67	5.07	8.30	1.21
8	A	6.83	20.01	80.51	4.83	7.83	1.22
	B	7.82	33.46	78.56	5.04	8.58	1.31
9	A	6.37	28.28	81.44	9.05	3.14	1.17
	B	6.44	33.49	80.15	5.13	8.28	1.13
10	A	6.61	27.67	80.93	4.83	7.63	1.26
	B	6.36	31.72	81.00	5.26	7.38	1.16
11	A	5.98	27.74	81.53	4.80	7.69	1.24
	B	6.34	32.24	80.42	5.15	8.09	1.21
Avg.	A	6.55	27.63	81.61	5.29	6.54	1.18
	B	6.92	32.34	80.25	5.10	7.73	1.19

* A: Fraction of the coal samples smaller than 100 mesh.

B: Fraction of the coal samples greater than 100 mesh.

TABLE 8-44

SPARK SOURCE MASS SPECTROMETRY DATA

Sample No: 2, Inlet. <100 mesh, Sample was Parr Oxygen Bombed

Concentration in mg/kg

Element	Conc.	Element	Conc.	Element	Conc.
Aluminum		Holmium		Rhodium	
Antimony		Hydrogen	NR	Rubidium	0.9
Arsenic	2	Indium		Ruthenium	
Barium	31	Iodine	0.08	Samarium	0.7
Beryllium	0.2	Iridium		Scandium	1
Bismuth		Iron	700	Selenium	0.8
Boron	0.6	Lanthanum	2	Silicon	MC
Bromine	0.3	Lead	2	Silver	
Cadmium	0.1	Lithium	8	Sodium	50
Calcium	MC	Lutetium		Strontium	6
Carbon	NR	Magnesium		Sulfur	>430
Cerium	3	Manganese	4	Tantalum	
Cesium	3	Mercury	NR	Tellurium	
Chlorine		Molybdenum	0.4	Terbium	
Chromium		Neodymium	0.8	Thallium	
Cobalt	0.9	Nickel	0.8	Thorium	0.6
Copper	8	Niobium	1	Thulium	
Dysposium		Nitrogen	NR	Tin	0.7
Erbium		Osmium		Titanium	350
Europium	0.8	Oxygen	NR	Tungsten	
Fluorine	25	Palladium		Uranium	0.1
Gadolinium		Phosphorus	110	Vanadium	5
Gallium	0.2	Platinum		Ytterbium	
Germanium	0.1	Potassium	>900	Yttrium	2
Gold		Praseodymium	0.4	Zinc	7
Hafnium		Rhenium		Zirconium	4

NR - Not reported.
All elements not reported < 0.06 ppm weight.
MC - Major component,>1 g/kg

TABLE 8-45

SPARK SOURCE MASS SPECTROMETRY DATA

Sample No.: 2, Inlet, >100 Mesh, Sample was Parr Oxygen Bombed

Concentration in mg/kg

Element	Conc.	Element	Conc.	Element	Conc.
Aluminum		Holmium		Rhodium	
Antimony		Hydrogen	NR	Rubidium	2
Arsenic	0.3	Indium	STD	Ruthenium	
Barium	110	Iodine		Samarium	0.8
Beryllium	0.2	Iridium		Scandium	3
Bismuth		Iron	MC	Selenium	0.9
Boron	0.8	Lanthanum	7	Silicon	MC
Bromine	0.7	Lead	1	Silver	
Cadmium	0.2	Lithium	6	Sodium	MC
Calcium	MC	Lutetium		Strontium	60
Carbon	NR	Magnesium		Sulfur	>620
Cerium	12	Manganese	5	Tantalum	
Cesium		Mercury	NR	Tellurium	
Chlorine		Molybdenum	0.4	Terbium	
Chromium		Neodymium	0.3	Thallium	
Cobalt	2	Nickel	0.2	Thorium	3
Copper	4	Niobium	2	Thulium	
Dysposium		Nitrogen	NR	Tin	
Erbium		Osmium		Titanium	460
Europium	0.1	Oxygen	NR	Tungsten	
Fluorine	9	Palladium		Uranium	2
Gadolinium		Phosphorus	50	Vanadium	8
Gallium	3	Platinum	2	Ytterbium	
Germanium	0.1	Potassium	MC	Yttrium	8
Gold		Praseodymium	0.3	Zinc	4
Hafnium		Rhenium		Zirconium	15

NR - Not reported.
All elements not reported < 0.09 ppm weight.
MC - Major component, >1 g/kg

TABLE 8-46

SPARK SOURCE MASS SPECTROMETRY DATA

Sample No.: 2, Outlet, <100 Mesh, Sample was Parr Oxygen Bombed

Concentration in mg/kg

Element	Conc.	Element	Conc.	Element	Conc.
Aluminum		Holmium		Rhodium	
Antimony		Hydrogen	NR	Rubidium	3
Arsenic	3	Indium	STD	Ruthenium	
Barium	170	Iodine		Samarium	3
Beryllium	0.1	Iridium		Scandium	4
Bismuth		Iron	MC	Selenium	5
Boron	0.7	Lanthanum	7	Silicon	MC
Bromine	1	Lead	6	Silver	
Cadmium	0.3	Lithium	6	Sodium	400
Calcium	MC	Lutetium		Strontium	59
Carbon	NR	Magnesium	220	Sulfur	MC
Cerium	8	Manganese	7	Tantalum	
Cesium	0.2	Mercury	NR	Tellurium	
Chlorine		Molybdenum	0.5	Terbium	0.2
Chromium		Neodymium	2	Thallium	
Cobalt	1	Nickel	1	Thorium	
Copper	8	Niobium	4	Thulium	2
Dysposium		Nitrogen	NR	Tin	0.7
Erbium		Osmium		Titanium	190
Europium	0.2	Oxygen	NR	Tungsten	
Fluorine	23	Palladium		Uranium	1
Gadolinium	0.5	Phosphorus	91	Vanadium	10
Gallium	2	Platinum	1	Ytterbium	
Germanium	0.3	Potassium	MC	Yttrium	5
Gold		Praseodymium	2	Zinc	8
Hafnium		Rhenium		Zirconium	11

NR - Not reported.
All elements not reported < 0.1 ppm weight
MC - Major component, >1 g/kg

TABLE 8-47

SPARK SOURCE MASS SPECTROMETRY DATA

Sample No.: 2, Outlet, >100 mesh, Sample was Parr Oxygen Bombed

Concentration in mg/kg

Element	Conc.	Element	Conc.	Element	Conc.
Aluminum		Holmium		Rhodium	
Antimony		Hydrogen	NR	Rubidium	0.7
Arsenic	0.5	Indium	STD	Ruthenium	
Barium	190	Iodine		Samarium	0.7
Beryllium	0.5	Iridium		Scandium	2
Bismuth		Iron	400	Selenium	0.4
Boron	3	Lanthanum	7	Silicon	MC
Bromine	0.7	Lead	0.2	Silver	
Cadmium	0.1	Lithium	27	Sodium	MC
Calcium	MC	Lutetium		Strontium	100
Carbon	NR	Magnesium		Sulfur	490
Cerium	10	Manganese	2	Tantalum	
Cesium		Mercury	NR	Tellurium	
Chlorine		Molybdenum		Terbium	0.1
Chromium		Neodymium	2	Thallium	
Cobalt	1	Nickel		Thorium	1
Copper	4	Niobium	2	Thulium	
Dysposium		Nitrogen	NR	Tin	0.3
Erbium		Osmium		Titanium	370
Europium	0.1	Oxygen	NR	Tungsten	
Fluorine	220	Palladium		Uranium	0.5
Gadolinium	0.2	Phosphorus	110	Vanadium	5
Gallium	2	Platinum	1	Ytterbium	
Germanium	0.3	Potassium	MC	Yttrium	6
Gold		Praseodymium	1	Zinc	4
Hafnium		Rhenium		Zirconium	13

NR - Not reported.
All elements not reported < 0.07 ppm weight.
MC - Major component, >1 g/kg

TABLE 8-48

TRACE ELEMENTS IN COAL SAMPLES
(mg/kg)

Sample No. / Element	2, Inlet <100 Mesh	2, Inlet >100 Mesh	2, Outlet <100 Mesh	2, Outlet >100 Mesh
Barium	31	110	170	190
Calcium	>1000	>1000	>1000	>1000
Cerium	3	12	8	10
Copper	8	4	8	4
Flourine	25	9	23	220
Iron	700	>1000	>1000	400
Lanthanum	2	7	7	7
Lithium	8	6	6	27
Phosphorus	110	50	91	110
Potassium	>1000	>1000	>1000	>1000
Silicon	>1000	>1000	>1000	>1000
Sodium	50	>1000	400	>1000
Strontium	6	60	59	100
Sulfur	430	620	>1000	490
Titanium	350	460	190	370
Vanadium	5	8	10	5
Yttrium	2	8	5	6
Zinc	7	4	8	4
Zirconium	4	15	11	13

9.0 Discussion of Results

9.1 Particulate Emissions

YRC EPA-5 particulate results (section 8.3) are compared to results obtained by Betz Engineering in Tables 9-1 and 9-2. Outlet particulate loadings are consistent for the two test programs. The single YRC inlet test appears to be low in comparison with Betz data. A review of the sampling and analytical techniques used in the two test programs reveals no significant reason for this discrepancy. Betz analysis was aimed at obtaining total particulate weight before chloroform extraction. YRC particulate is reported as chloroform and non-chlorform soluables and no weighing was done before chloroform extraction.

Particulate loadings obtained from the POM and BSO analysis (section 8.1 and 8.4) are compared in Table 9-3. BSO results have been adjusted to reflect front half and filter loadings only. The particulate loadings for the two sets of tests are consistent, given the variability of the results. POM particulate weight was obtained after methylene chloride and acetone washes of the front half (Section 7.1). BSO particulate weight was obtained after benzene and acetone washes of the front half (Section 7.3). A significantly greater proportion of the POM particulate was contributed by the filter catch than was the case with the BSO results.

In general, the particulate loadings given by these two sets of tests are consistent with the Betz data in Table 9-1.

TABLE 9-1

COMPARISON OF YRC AND B.E.E.

EPA-5 PARTICULATE DATA

Process Conditions*	Inlet mg/Nm^3	Outlet mg/Nm^3	Source**	Test No.
82/271	-	610	YRC	3
	18510	888		15
	19379	764		16
	16291	1329		18
95/271	17091	895		13
	16085	1114		14
	17778	892		17
	8196	1564	YRC	2
109/271	15216	1588		8
	13110	1252		10
	16359	1311		11
76/278	-	429	YRC	1
82/288	13980	1360		1
	16794	760		2
	21850	748		12
95/288	14896	1448		4
	9770	2045		5
	11989	529		9
109/288	14597	1890		3
	11737	2274		6
	16016	2620		7

* (M-Tons Coal/Hr.)/(Preheater Oultet Temp., ^{o}C)
** Source is B.E.E. unless noted.

TABLE 9-2

COMPARISON OF YRC AND B.E.E.
PARTICULATE DATA - PA-DER METHOD

Process Conditions*	Inlet mg/Nm^3	Outlet mg/Nm^3	Source**	/Test No.
82/271	-	1636	YRC	3
	18968	1085		15
	19723	924		16
	17068	1691		18
95/271	17457	1202		13
	16336	1608		14
	18647	1146		17
	9025	1430	YRC	2
109/271	16222	1878		8
	13339	1764		10
	17023	1732		11
76/278	-	953	YRC	1
82/288	14529	1531		1
	18212	898		2
	22056	1643		12
95/288	15947	2218		4
	10571	2558		5
	12424	666		9
109/288	15764	2103		3
	12241	2622		6
	17342	3224		7

* (M-tons Coal/hr)/(Preheater Outlet Temp. ^{o}C)

** Source is B.E.E. unless noted

TABLE 9-3

COMPARISON OF PARTICULATE DATA
FROM POM AND BSO SAMPLES
(FRONT HALF)

Process Conditions*	Inlet mg/Nm^3	Outlet mg/Nm^3	Test
82/260	14973	1256	POM-11
109/260	-	755	POM-4
82/271	20986	375	POM-10
	10424	94	POM-2
	10046	269	BOS-1
83/271	4322	355	POM-3
109/271	13060	1274	POM-8
	7804.7	2277	BSO-2
55/288	16392.4	280	BSO-3
82/288	-	1091	POM-7
108/288	-	1668	POM-6
	-	1700	POM-5

* (M-Tons Coal/Hr)/ (Preheater Outlet Temp., ^{o}C)

9.2 Chloroform and Non-Chloroform Soluable Emissions

YRC and Betz chloroform soluable organic results are compared in Table 9-4. YRC results appear to be low in comparison with Betz data. Table 9-5 gives the percent chloroform solubles for YRC and Betz Data. This shows that Betz obtained a larger percentage of chloroform soluable material in the front half of their train than did YRC. A comparison of the PA-DER results shows that YRC obtained a higher percentage of chloroform soluables in the back half.

Tables 9-6 to 9-9 list Betz chloroform and non-chloroform soluables by sampling train components.

TABLE 9-4

COMPARISON OF YRC AND BETZ
CHLOROFORM SOLUABLE ORGANIC DATA
(EPA METHOD 5)

Process Conditions*	Inlet mg/Nm^3	Outlet mg/Nm^3	Source** /	Test No.
82/271	-	143	YRC	3
	1964	380		15
	938	604		16
	803	840		18
95/271	510	410	YRC	2
	817	709		13
	1899	817		14
	1352	764		17
109/271	2551	1151		8
	2606	1036		10
	4281	1071		11
76/278	-	110	YRC	1
82/288	984	1144		1
	1071	659		2
	2139	565		12
95/288	952	849		4
	1405	1750		5
	2707	403		9
109/288	1830	1636		3
	4249	1931		6
	3867	1794		7

* (M-Tons Coal/Hr)/(Preheater Outlet Temp. ^{o}C)

** Source is B.E.E. unless noted.

TABLE 9-5

COMPARISON OF YRC AND B.E.E. DATA
PERCENT CHLOROFORM SOLUABLE PARTICULATE

Process Conditions*	Inlet E.P.A.	Inlet PA-DER[1]	Outlet E.P.A.	Outlet PA-DER[1]	Source**/Test No.
82/271	-	-	23.50	73.04	YRC-3
	7.04	7.42	83.64	78.56	15
	6.37	7.59	86.80	82.53	16
	9.79	10.13	75.41	52.50	18
95/271	6.49	9.53	58.55	57.69	13
	14.38	17.37	85.63	79.62	14
	22.59	22.76	76.31	73.20	17
	6.22	11.26	39.33	48.23	YRC-2
109/271	12.55	13.93	86.63	81.34	8
	36.17	35.93	84.94	77.77	10
	24.13	23.63	68.50	67.27	11
76/278	-	-	25.58	83.72	YRC-1
82/288	10.29	10.40	42.92	48.82	1
	4.85	6.75	79.06	74.56	2
	4.88	5.47	63.26	55.94	12
95/288	4.78	5.16	79.17	61.44	4
	11.81	11.92	73.33	67.44	5
	7.61	8.19	85.80	79.58	9
109/288	16.76	16.67	72.47	69.33	3
	19.89	20.19	82.81	67.88	6
	26.20	25.92	81.65	63.42	7

* (M-Tons Coal/Hr)/(Preheater Outlet Temp., ^{o}C)
** Source is B.E.E. unless noted.
[1] included silica gel.

TABLE 9-6

BREAKDOWN OF BETZ CHLOROFORM SOLUABLE DATA
BY SAMPLING TRAIN COMPONENTS

SCRUBBER INLET
mg/Nm^3

Process Conditions*	FH	F	BH	SG	T	Test No.
82/271	306	1603	68	99	2076	15
	357	584	53	339	1334	16
	479	326	130	19	954	18
95/271	520	299	83	113	1015	13
	308	1595	50	21	1974	14
	301	1053	176	24	1554	17
109/271	567	1987	154	245	2953	8
	544	2070	85	40	2739	10
	414	3884	128	25	4451	11
82/288	155	832	95	303	1385	1
	192	880	313	84	1471	2
	341	1803	96	459	2698	12
95/288	214	752	555	589	2110	4
	331	1076	431	182	2020	5
	924	1790	121	17	2851	9
109/288	655	1181	367	331	2534	3
	976	3278	148	995	5398	6
	1471	2401	230	357	2946	7

* (M-Tons Coal/Hr)/(Preheater Outlet Temp. ^{o}C)

FH = Nozzle, Probe, Front Half Filter Holder

F = Filter

BH = Back Half Filter Holder, Impinger Lines, Impiners, Impinger Solutions

SG = Silica Gel

T = Total

TABLE 9-7

BREAKDOWN OF BETZ CHLOROFORM SOLUABLE DATA
BY SAMPLING TRAIN COMPONENTS

SCRUBBER OUTLET
mg/Nm^3

Process Conditions*	FH	F	BH	SG	T	Test No.
82/271	6	376	149	32	562	15
	195	411	86	354	1045	16
	796	47	106	1754	2703	18
95/271	233	476	31	222	963	13
	295	523	269	40	1127	14
	394	373	146	73	985	17
109/271	303	851	151	44	1349	8
	327	711	161	537	1737	10
	300	723	29	424	1526	11
82/288	119	1028	58	111	1316	1
	71	590	83	362	1106	2
	305	262	298	271	1135	12
95/288	389	461	549	263	1545	4
	294	1459	286	227	2267	5
	197	206	86	405	894	9
109/288	92	1545	74	78	1793	3
	316	1619	108	367	2411	6
	346	1454	374	165	2338	7

* (M-Tons Coal/Hr)/(Preheater Outlet Temp., ^{o}C)

FH = Nozzle, Probe, Front Half Filter Holder

F = Filter

BH = Back Half Filter Holder, Impinger Lines, Impingers, Impinger Solutions

SG = Silica Gel

T = Total

TABLE 9-8

BREAKDOWN OF BETZ NON-CHLOROFORM SOLUABLE DATA

(TOTAL LESS CHLOROFORM SOLUABLES)

SCRUBBER INLET

mg/Nm^3

Process Conditions*	FH	F	BH	T	Test No.
82/271	4641	12005	305	16675	15
	4654	13825	291	18770	16
	2047	13629	481	16156	18
95/271	4642	11662	274	16578	13
	6171	8027	219	14423	14
	4803	11644	710	17157	17
109/271	3254	8138	844	13535	8
	4421	6110	139	10671	10
	8422	3641	538	12601	11
83/288	2187	10838	460	13485	1
	3490	12266	1113	16869	2
	6964	12791	110	19867	12
95/288	3128	10797	507	14434	4
	3128	5248	372	8749	5
	4550	4764	320	9619	9
109/288	3967	8824	821	13613	3
	4410	3097	346	7853	6
	4649	7523	1087	13259	7

* (M-Tons Coal/Hr)/(Preheater Outlet Temp., ^{o}C)

FH = Nozzle, Probe, Front Half Filter Holder

F = Filter

BH = Back Half Filter Holder, Impinger Lines, Impingers, Impinger Solutions

T = Total

TABLE 9-9

BREAKDOWN OF BETZ NON-CHLOROFORM SOLUABLE DATA

(TOTAL LESS CHLOROFORM SOLUABLES)

SCRUBBER OUTLET

mg/Nm^3

Process Conditions*	FH	F	BH	T	Test No.
82/271	461	47	49	556	15
	136	25	74	235	16
	481	8	257	747	18
95/271	113	74	278	465	13
	168	130	228	525	14
	108	18	107	234	17
109/271	149	289	139	577	8
	90	125	352	568	10
	95	146	394	635	11
82/288	107	117	105	329	1
	45	56	57	157	2
	100	85	598	782	12
95/288	175	427	221	823	4
	128	166	228	522	5
	98	28	54	179	9
109/288	63	190	140	274	3
	172	171	241	584	6
	218	610	232	1060	7

* (M-Tons Coal/Hr)/(Preheater Outlet Temp., ^{o}C)

9.3 Benzine and Total Hydrocarbons in Grab Samples

The results of the benzene and total hydrocarbon analysis (Table 8-39) show that, for the gas stream, the concentrations of these materials increases across the scrubber (that is, from inlet to outlet). In five of the eight tests, the benzene concentration was below the detection limit (0.8ppm) at the scrubber inlet and yet was as high as 23.0 ppm at the outlet for one of these tests. Some samples show a similar increase in total hydrocarbon content. However, there appears to be no correlation between benzene concentration and total hydrocarbon concentration in the individual tests.

Of the six water grab samples, none showed a benzene concentration above the detection limit of 5 ppm. However, it seems likely that the source of the benzene in the gas samples was indeed the water stream. As noted in section 8.7, it is possible that the benzene content of the water samples was lost prior to analysis. The gas samples were analyzed soon after testing with an on site GC. When benzene was found, it was decided to analyze the water grab samples, which had already been taken for the POM GC/MS analysis, for benzene also. Hence, there was a substantial delay in the water sample analysis.

The scrubber water treatment system is described in section 5.3 The flotation cells and disc filter are open tanks and,as such, are possible sources of accidental water system contamination. However, the consistency of the data over the

nine day testing period does not suggest this.

The coal distribution and charging bins are pressurized at appropriate times with steam. The steam is vented during depressurization into either the distribution bin vent condenser or the charging bin vent condenser. The condensate from each of these tanks flows to the scrubber water pumping tank. It may be possible that light hydrocarbons, including benzene, are volatalized from the coal during bin pressurization. They would then be vented and ultimately condensed or absorbed into the scrubber water. In the scrubber, the benzine and light hydrocarbons could again be volatilized by the combined effects of spraying and increasing water temperature. This would account for the higher gas outlet concentrations of both the benzene and the total organics.

The above is presented only as a possible explanation of the testing results and there is no real evidence to support such a possibility. Other sources of benzene and light hydrocarbons are unknown. Further testing would be required, especially on the inlet water, to determine the correct explanations.

9.4 POM Analysis Discussion

In reviewing the large amount of POM data collected by GC/MS analysis, two major observations can be made:

1. The concentrations of individual POM species vary over an extremely wide range from test to test and do not appear to consistently increase or decrease across the scrubber from inlet to outlet.

2. The total POM concentration for both the gas and water streams decrease across the scrubber; i.e., from inlet to outlet.

In addressing the first observation above, it is first noted that sampling difficulties were encountered, as explained in Section 6.12, which limited the simultaneity of the inlet and outlet gas stream tests. These included process shutdowns, process fluctuations, and high moisture and grain loadings which necessitated many filter changes, especially at the inlet. This lack of strict simultaneity may have affected the inlet vs. outlet results significantly if changes in specific POM concentrations occur very rapidly. In support of this, it is shown in Tables 8-5 through 8-15 that the concentrations of specific POMs vary by as much as a factor of 10 from test to test. While the total POM concentration is more consistent, it also may range between 3 and 11% of the aromatic fraction which, in turn, represents between 3 and 14% of the total organic extract. This is shown in Section 8.2.5. The total organic fraction is shown to vary from sample to sample in Table 8-19.

These variations are probably due to natural variations in the quantity and composition of the coal being processed. Further, one of the by-products of the coking process, coke oven gas, is used as fuel for the preheater. Since the coke oven gas is composed of the volatile gas driven from the coal during coking, a large amount of POM material should be expected in this gas. In general,POM and other hydrocarbons should be completely consumed during combustion; however, the composition and heat content of C.O.G. is highly variable. Since the C.O.G. is burned at very low percent excess air, it is likely that, at times, slugs of high heat content C.O.G. will not have sufficient combustion air with the result that quantities of unburned hydrocarbons will be released into the preheater gas stream. This would cause high concentrations of very short duration which would affect the sampling results. The inlet samples would tend to be the most affected because of the inertia effect of the scrubber.

The problem, then, may be in the nature and duration of the sampling. Very long test periods would tend to even out the effects of pulses of organic material. Very short, simultaneous tests would give an indication of the response of the scrubber system to hydrocarbon pulses. In either case, sampling of the C.O.G. should be carried out in order to ascertain if this is indeed a source of hydrocarbon variation.

The second observation noted above is concerned with the fact that the total POM concentration of both the gas and water streams decreases across the scrubber (from inlet to outlet). It should be expected that one stream would increase in concentration at

at expense of the other stream.

Raoult's Law relates the liquid/gas phase concentrations of a component in an ideal solution at equilibrium conditions. The solutions in the scrubber are neither ideal nor at equilibrium but an "order of magnitude" analysis based on Raoult's Law will indicate whether POM's should be absorbed or released by the water stream.

Raoult's Law is

$$yP_T = xPv$$

where y = the mole fraction (POM) in the gas stream.

x = the mole fraction (POM) in the water stream.

P_T = the total pressure of the gas

Pv = the vapor pressure of the particular POM in the water stream.

Napthalene is the most easily volatilized of the POM species tested for and has a vapor pressure of 0.123 mm Hg at 20°C. The vapor pressures of the other POM's are less than this by a factor of 10 to 1000 depending on their molecular weight. Hence, their concentration in water should be greater than Napthalene, at equilibrium. The Naphthalene concentration is on the order of 1 mg/Nm^3 which is equivalent to 7.8×10^{-6} moles per Nm^3. The mole fraction, y, is 1.75×10^{-7} (based on 44.7 moles of air per Nm^3). Assuming the total pressure, P_T, in the scrubber to be 720 mm Hg, the mole fraction, x, of napthalene in water is calculated by Raoult's Law to be 1.02×10^{-3}. This represents about 60 moles of napthalene (assuming 5.56×10^4 moles of water per m^3) or a concentration of about 8000 mg/l. This is about 1000 times higher than the observed concentration in the water and is a good indica-

tion that POM's should be absorbed by the water stream as it flows through the scrubber.

A possible explanation of the POM concentrations in the scrubber water is suggested by the higher particulate loading in the outlet water. Carbon is an excellent adsorber of organic compounds. The particulate matter in the water stream has a high percentage of coal particles which are essentially carbon. Therefore, if the carbon particles were adsorbing POM's, the outlet water POM concentration would appear to be lower than the inlet concentration because of the large amount of particulate matter in the outlet sample.

In order to determine if this explanation is correct, the particulate matter in the outlet and inlet samples would have to have been desorbed during analysis. Unfortunately, only the liquid extract was analyzed after the samples had been stored for quite some time.

Analysis of the liquid extract and filtered material is suggested for future sampling.

10.0 Effects of Process Condition

10.1 Particulate Emissions

Total particulate (PA-DER Method) at the scrubber inlet is relatively unaffected by preheater outlet temperature, as shown in Figure 10-1. Lowest concentrations occur at a coal feed rate of 95 M-ton/hr.

Scrubber outlet total particulate concentrations rise with both increasing preheater outlet temperature and increasing coal feed rate, as shown in Figure 10-2. Consequently, scrubber efficiency decreases as the coal feed rate and preheater outlet temperature is increased.

Particulate loadings obtained from POM samples also show no trends with changing process conditions at the scrubber inlet (Figure 10-4) but increase at the outlet with both increasing preheater outlet temperature and coal feed rate (Figure 10-5)

Again, scrubber efficiency decreases with increasing process conditions. (Figure 10-5)

10.2 Organic Emissions

Benzine soluable organic concentrations increase primarily with increasing coal feed rate as shown in Figure 10-6. Scrubber efficiency for the benzine soluables is low; 30% at 271°C, zero at 288°C. Chloroform soluable organic concentrations at the scrubber inlet increase mostly with increasing preheater outlet temperature at coal feed rates below 95 M-ton/hr but show a strong increase with increasing coal feed rates above this (see Figure 10-7). Outlet concentrations of chloroform soluables shown essentially a linear increase with increasing process conditions but the effect of preheater outlet temperature appears to be slightly greater as shown in Figure 10-8. Scrubber efficiency is generally lowest at a coal feed rate of 95 M-tons/hr and increases to a maximum of approximately 55% at a feed rate of 109 M-ton/hr. (See Figure 10-9)

10.3 POM Emissions

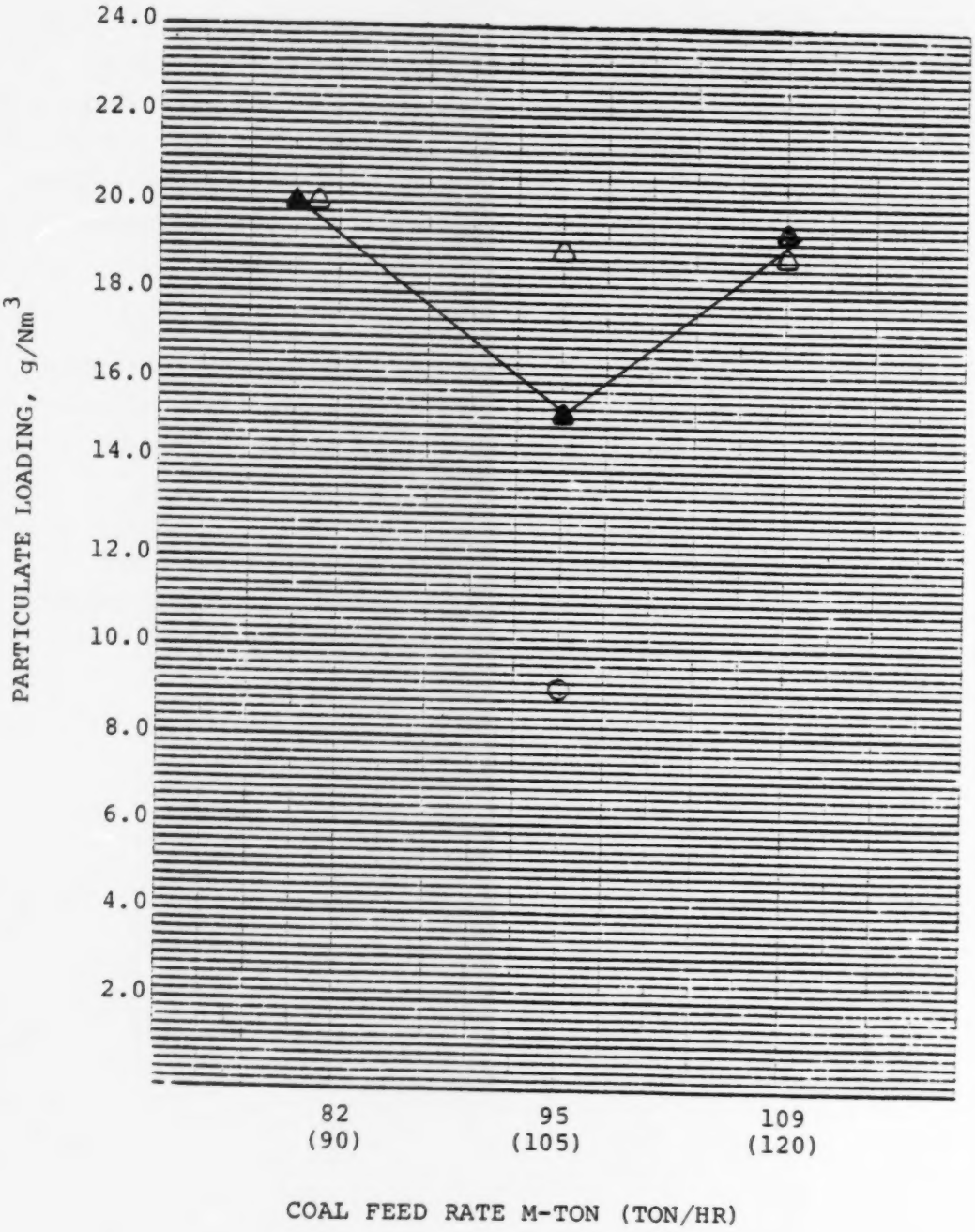
At the scrubber inlet, total POM concentrations are increased substantially with increasing coal feed rate as shown in Figure 10-10. The effect of preheater outlet temperature in not clear; at a feed rate of 82 M-ton/hr, the lowest total POM concentration is at a temperature of 271°C. At temperatures above and below this, there is an increase in concentration. The effect of temperature at higher feed rates becomes less.

Figure 10-11 shows total POM concentrations at the scrubber outlet. At the high preheater outlet temperature of 288°C, increasing feed rate has very little effect. At lower temperatures, concentrations rise sharply with increasing feed rate.

In general, scrubber efficiency for total POM increases from approximately 20% at a feed rate of 82 M-tons/hr to approximately 60% at 109 M-tons/hr. Preheater outlet temperature has little effect.

FIGURE

EFFECT OF COAL FEED RATE AND PREHEATER OUTLET TEMPERATURE ON TOTAL PARTICULATE (PA-DER METHOD) AT SCRUBBER INLET



LEGEND

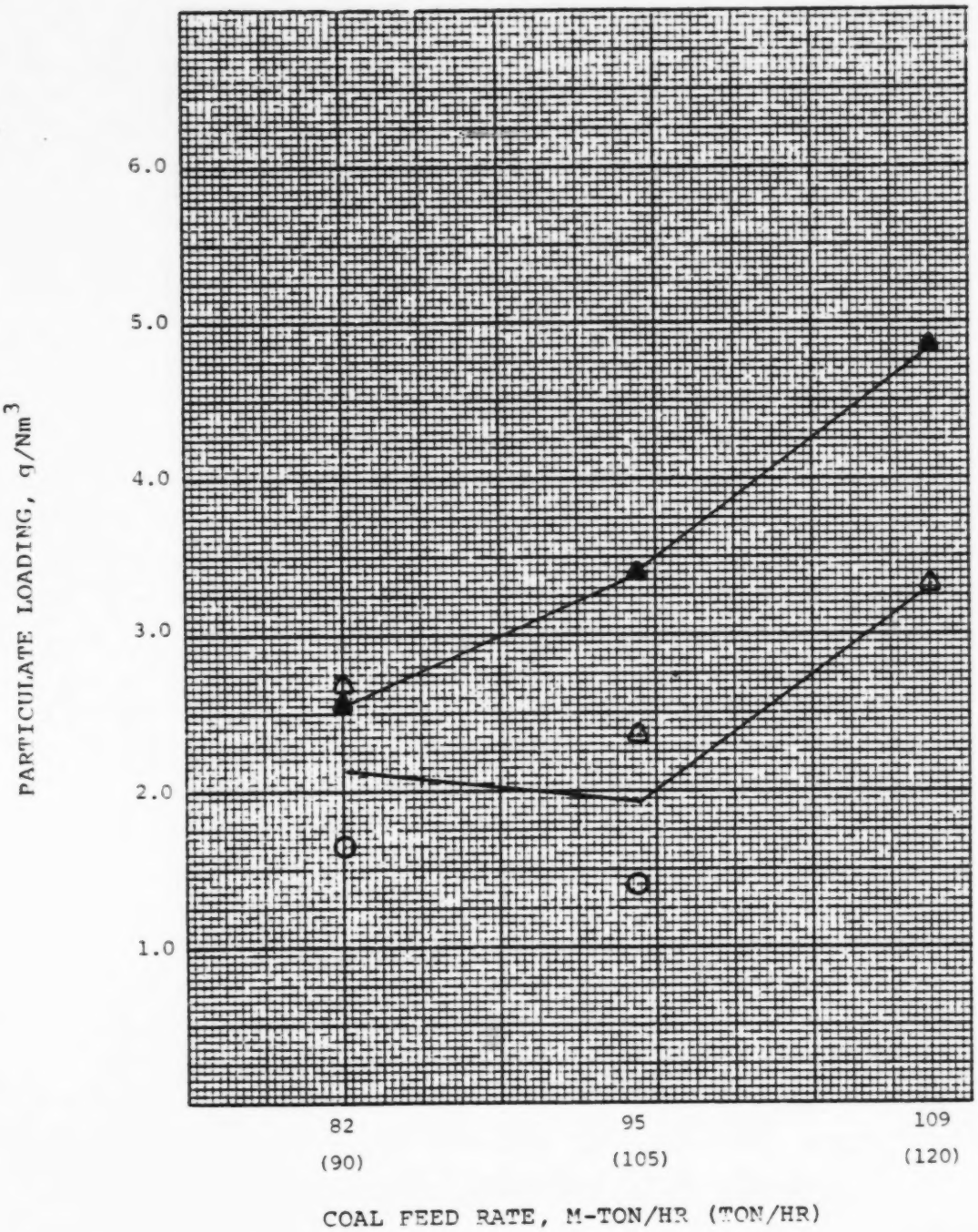
△ AVE BETZ @ 271°C (520°)

▲ AVE BETZ @ 288°C (550°)

○ YRC @ 271° (520°)

FIGURE 10-2

EFFECT OF COAL FEED RATE AND PREHEATER OUTLET TEMPERATURE ON TOTAL PARTICULATE (PA-DER METHOD) AT SCRUBBER OUTLET

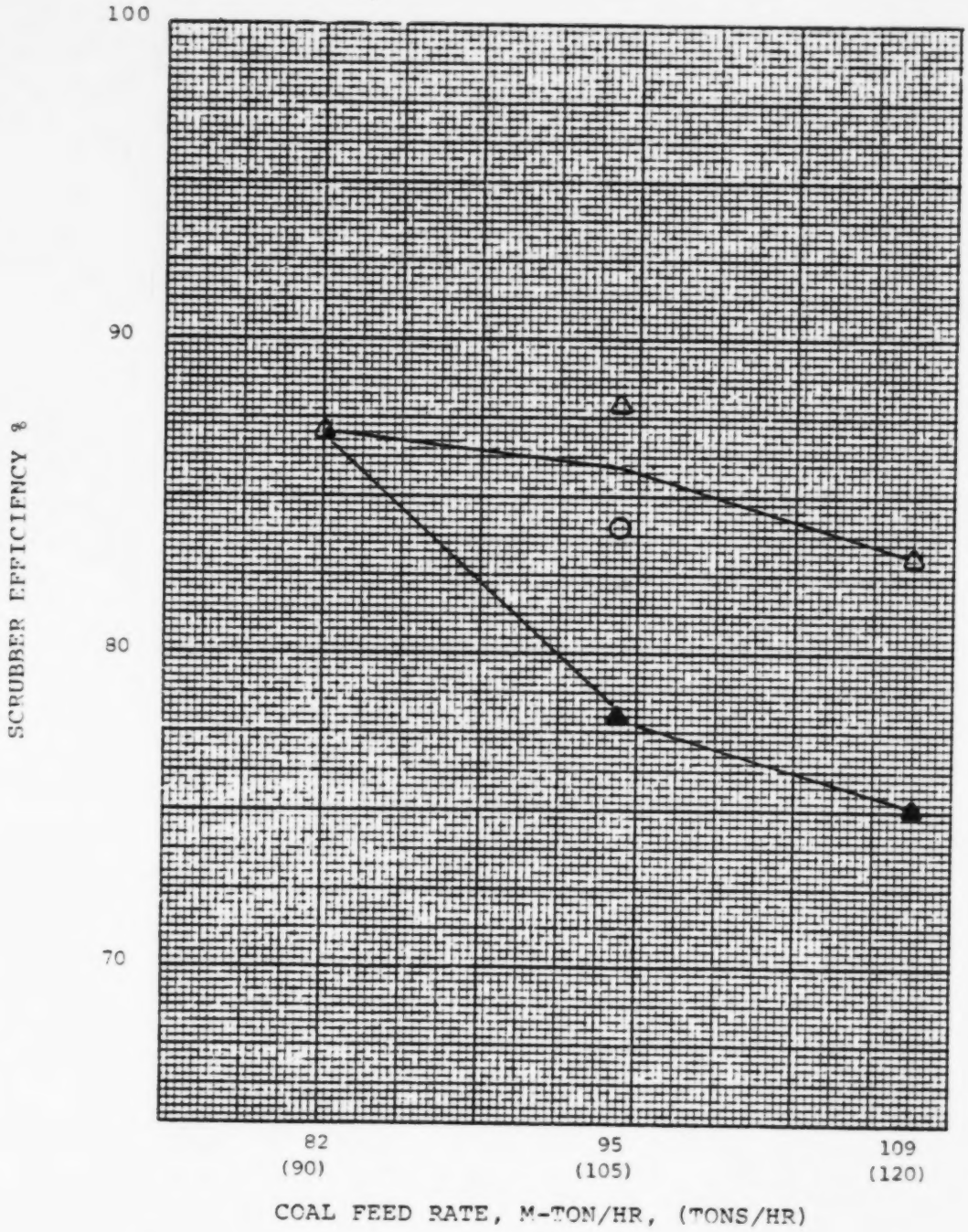


LEGEND

AVE. BETZ @ 271°C (520°F)
AVE. BETZ @ 288°C (550°F)
YRC @ 271°C (520°F)

FIGURE 10-3

EFFECT OF COAL FEED RATE AND PREHEATER OUTLET TEMPERATURE ON TOTAL PARTICULATE SCRUBBER EFFICIENCY (PA-DEP METHOD)

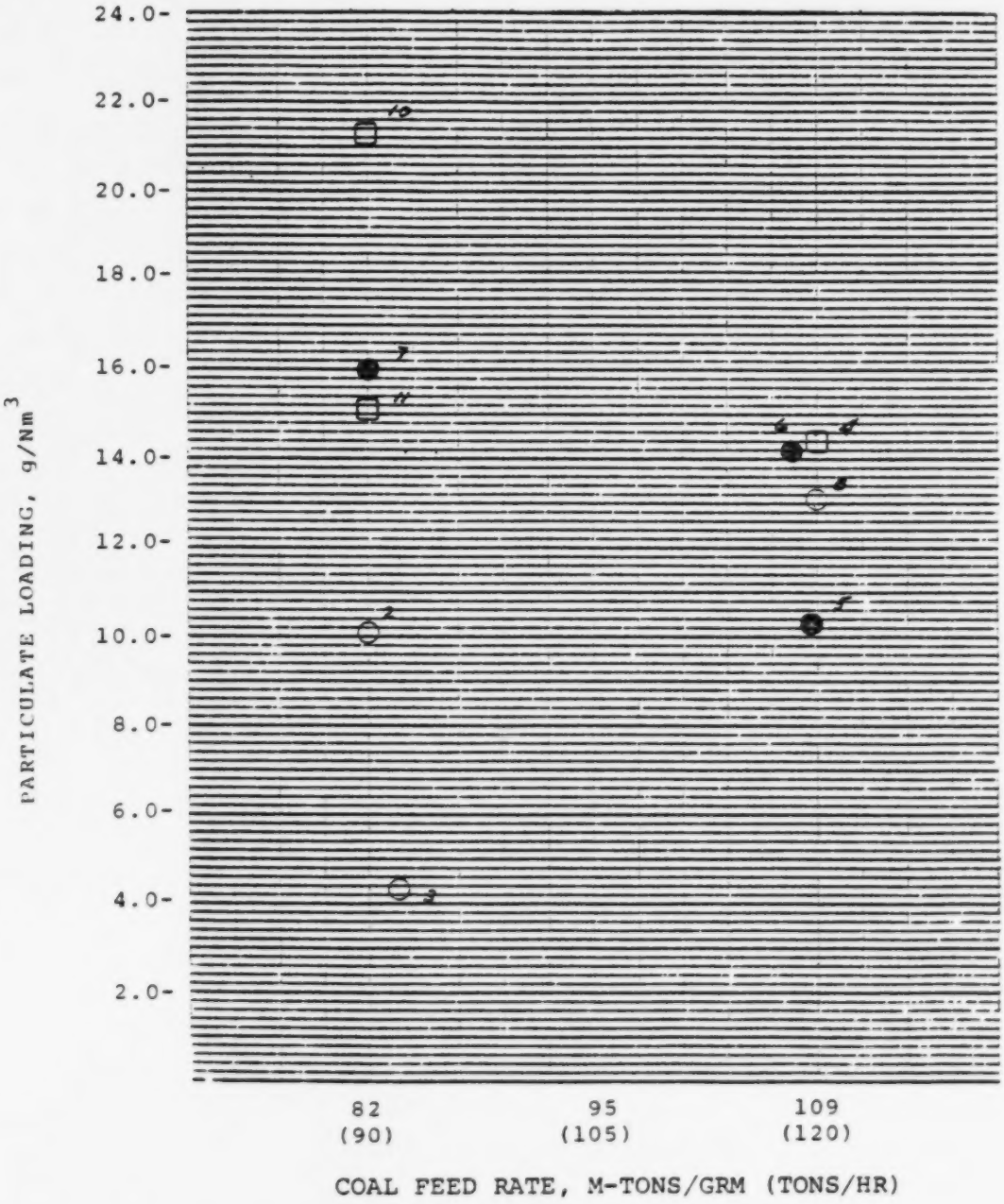


LEGEND

AVE. BETZ @ 271°C (520°F)
AVE. BETZ @ 288°C (550°F)
YRC @ 271°C (520°F)

FIGURE 10-4

EFFECT OF COAL FEED RATE AND PREHEATER OUTLET TEMPERATURE ON POM-TRAIN PARTICULATE AT SCRUBBER INLET



LEGEND:

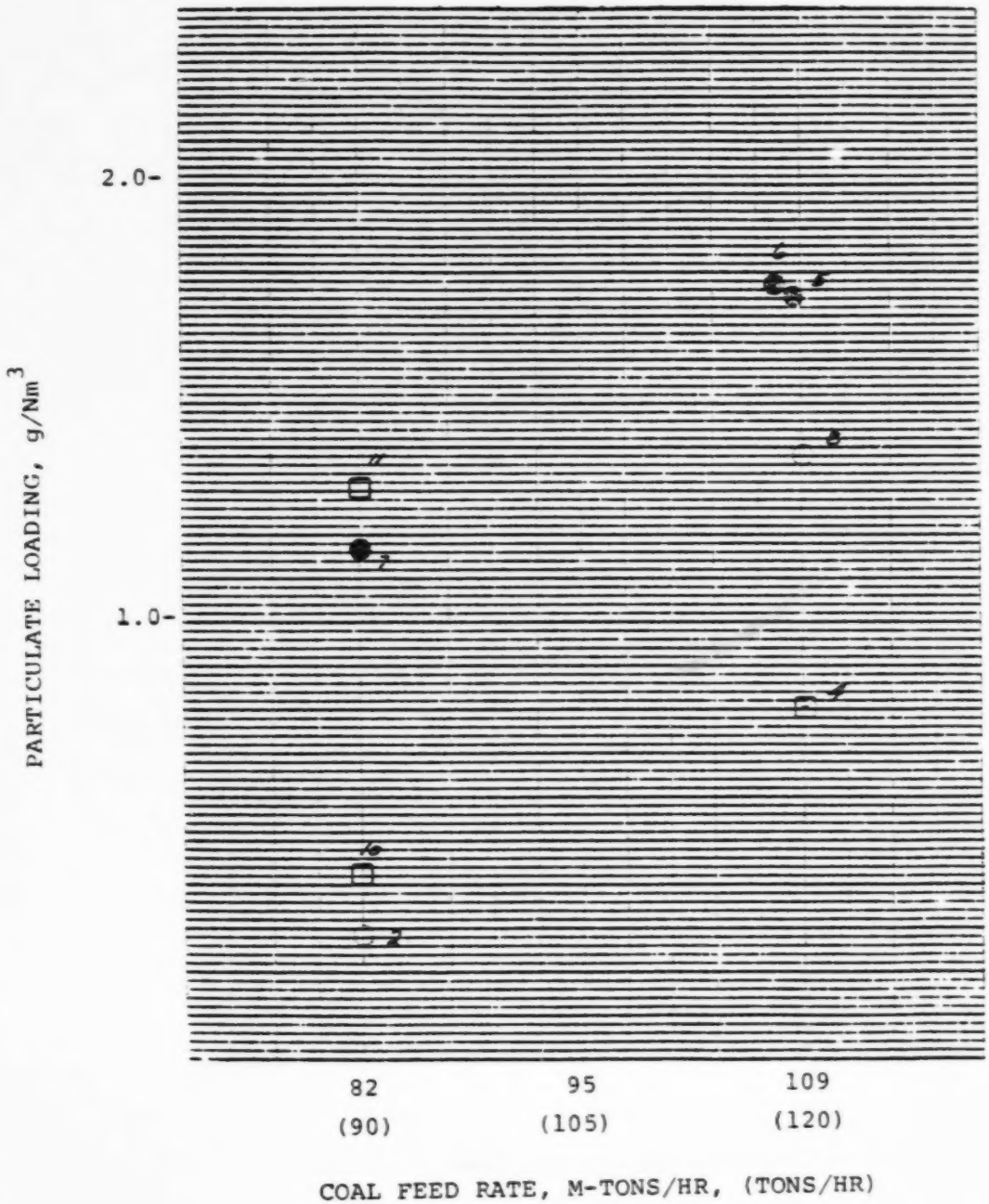
□ YRC @ 260°C (500°F)

○ YRC @ 271°C (520°F)

● YRC @ 288°C (550°F)

FIGURE

EFFECT OF COAL FEED RATE AND PREHEATER OUTLET TEMPERATURE ON POM-TRAIN PARTICULATE AT SCRUBBER OUTLET

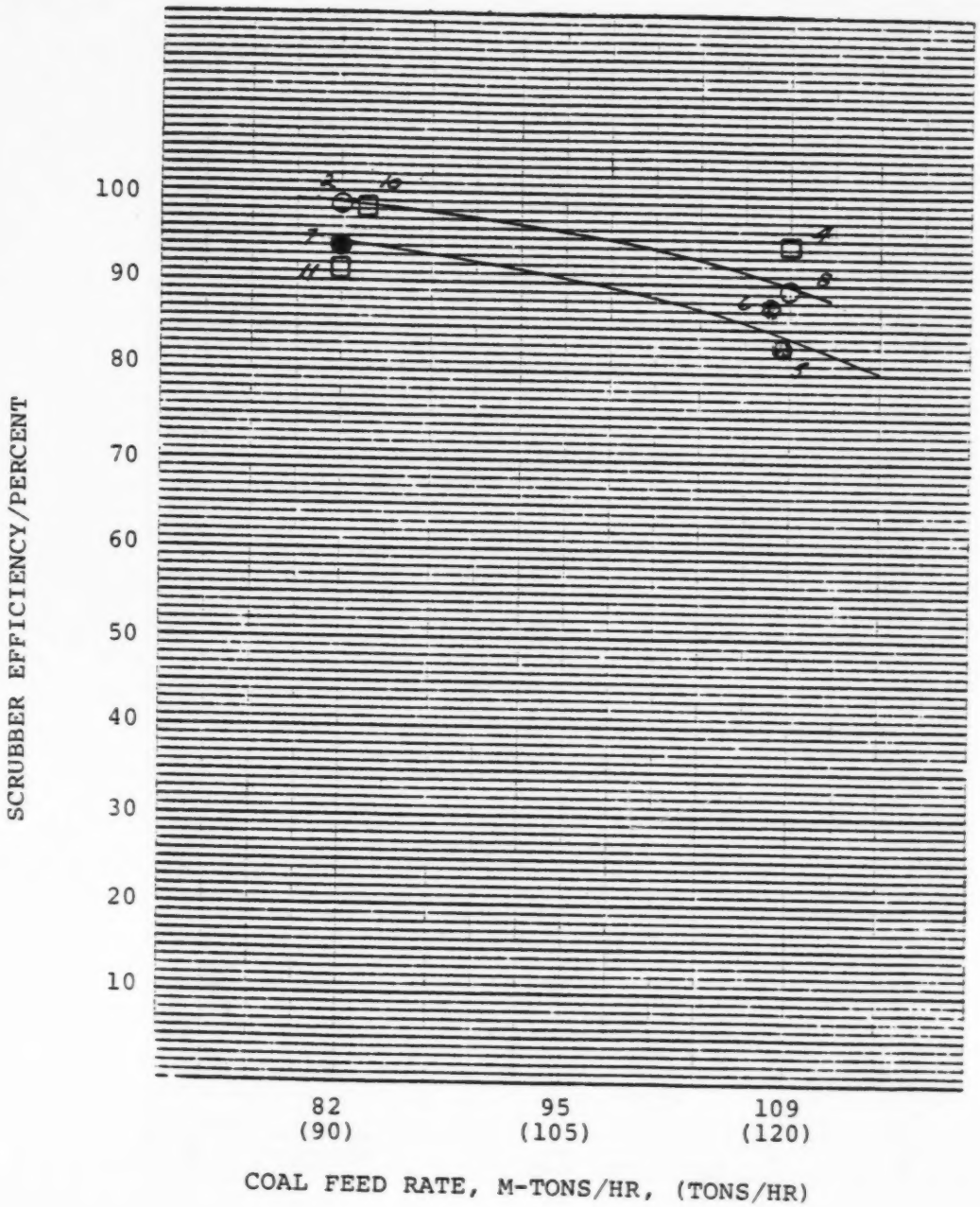


LEGEND:

□	YRC @ 260°C (500°F)
○	YRC @ 271°C (520°F)
●	YRC @ 288°C (550°F)

FIGURE 10-6

EFFECT OF COAL FEED RATE AND PREHEATER OUTLET TEMPERATURE ON SCRUBBER EFFICIENCY (POM PARTICULATE)

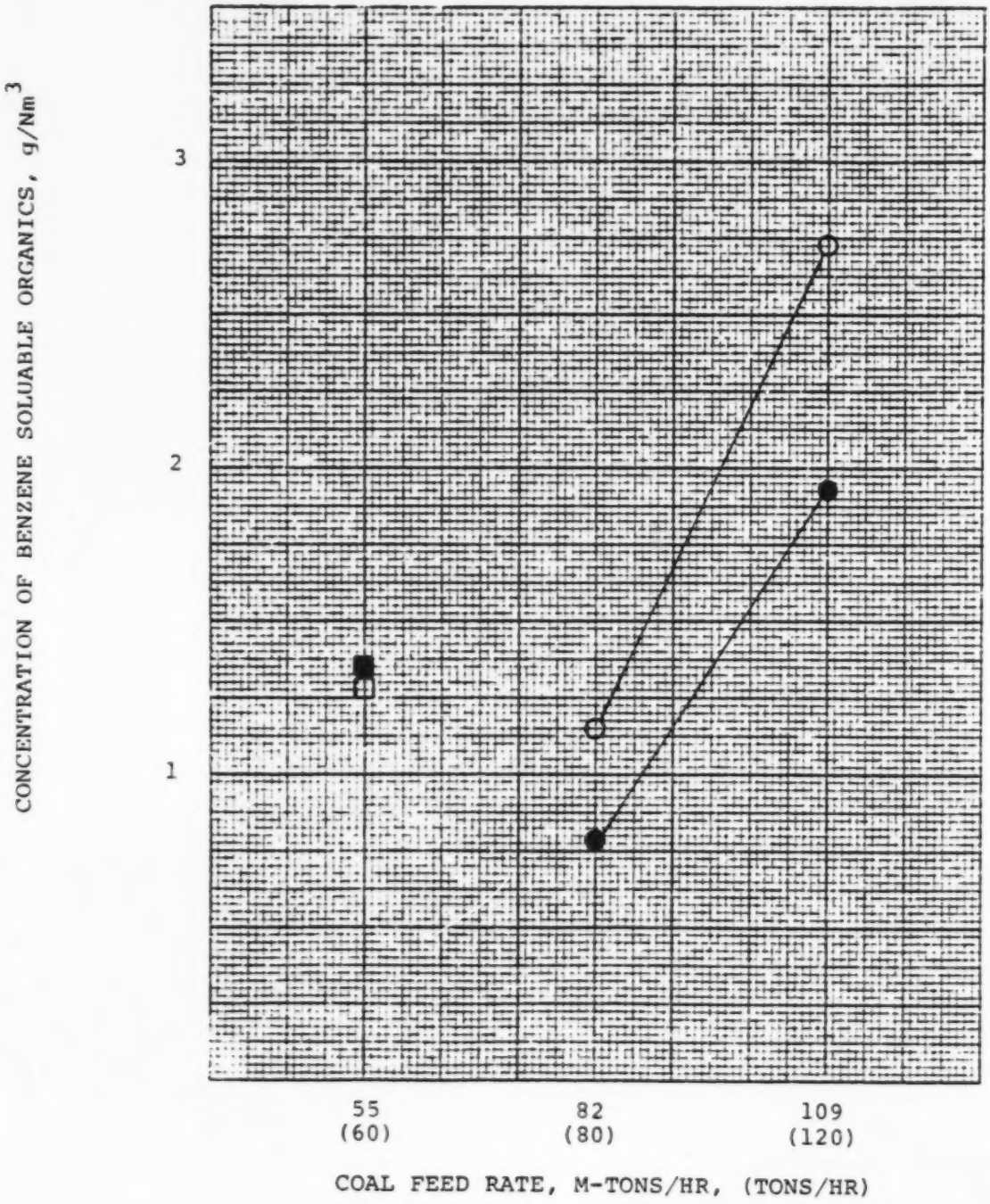


LEGEND

□ YRC @ 260°C (500°F)
○ YRC @ 271°C (520°F)
● YRC @ 288°C (550°F)

FIGURE 10-7

EFFECT OF COAL FEED RATE AND PREHEATER OUTLET TEMPERATURE ON BENZENE SOLUABLE ORGANIC CONCENTRATIONS



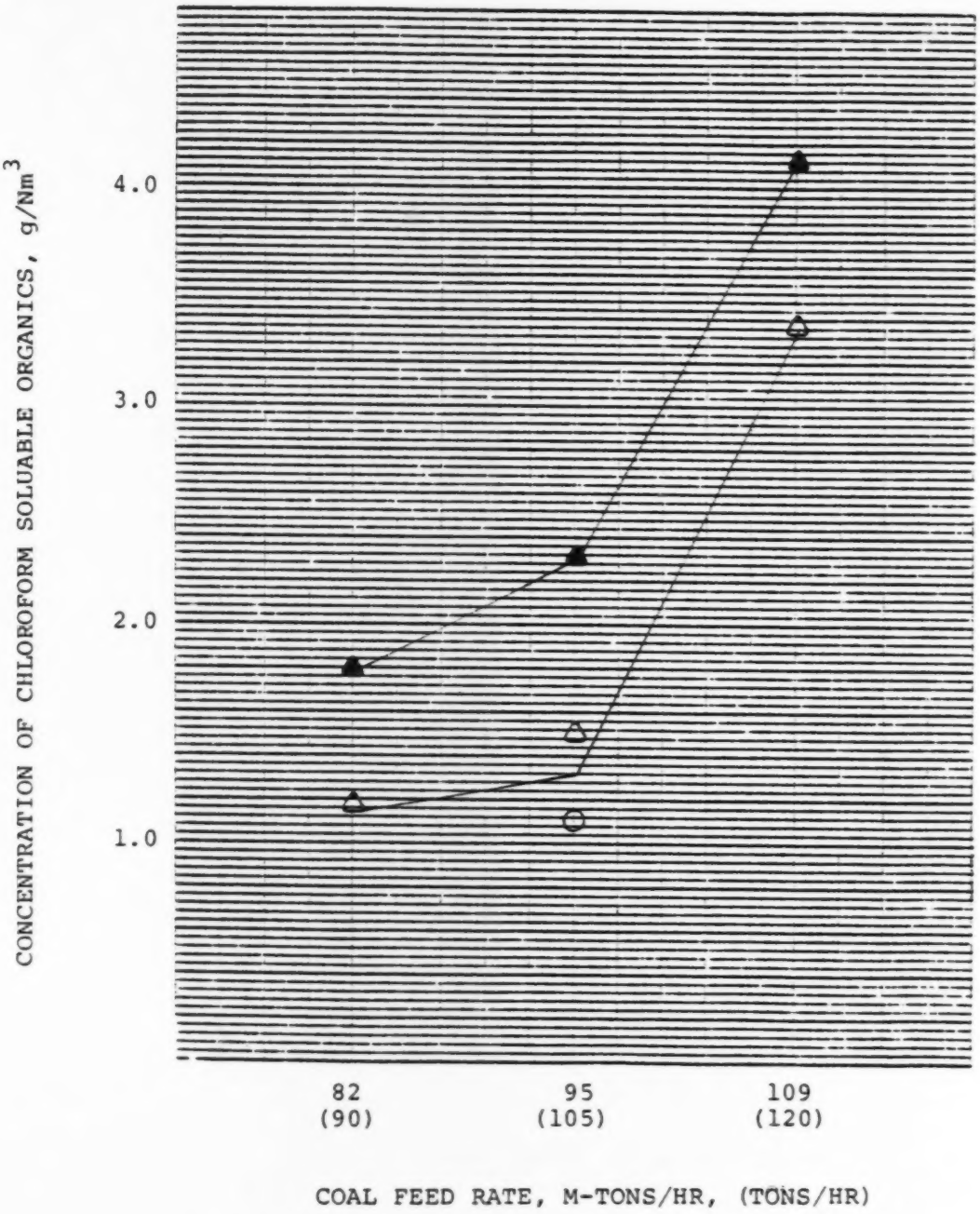
LEGEND

YRC @ 271°C (520°F); ○ = INLET, ● = OUTLET

YRC @ 288°C (550°F); □ = INLET, ■ = OUTLET

FIGURE 10-8

EFFECT OF COAL FEED RATE AND PREHEATER OUTLET TEMPERATURE ON THE CONCENTRATION OF CHLOROFORM SOLUABLE ORGANICS (PA-DER METHOD) AT THE SCRUBBER INLET



LEGEND

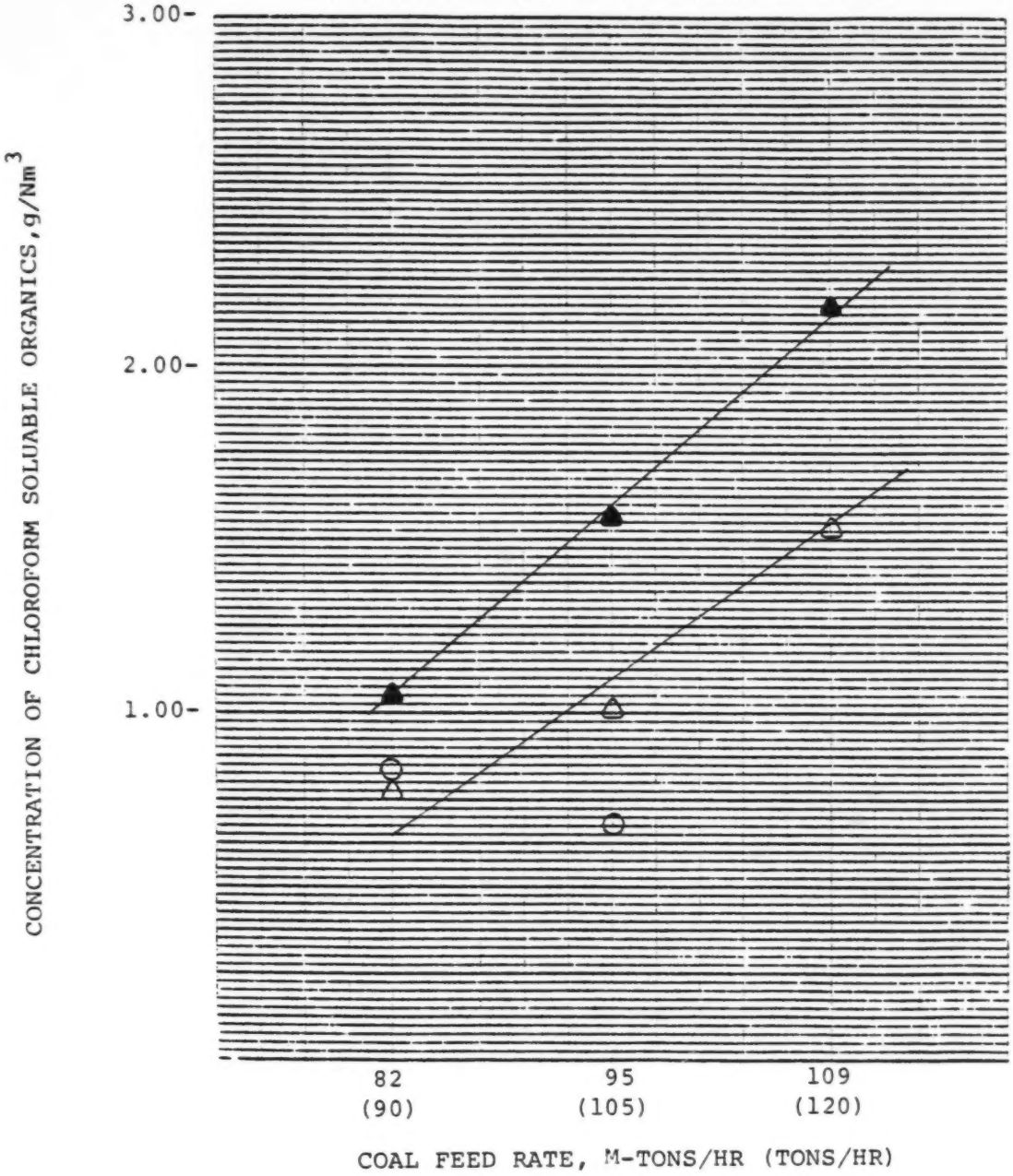
○ AVE. YRC @ 271°C, (520°F)

△ AVE. BETZ @ 271°C, (520°F)

▲ AVE. BETZ @ 288°C, (550°F)

FIGURE 10-9

EFFECT OF COAL FEED RATE AND PREHEATER OUTLET TEMPERATURE ON THE CONCENTRATION OF CHLOROFORM SOLUABLE ORGANICS (PA-DER METHOD) AT THE SCRUBBER OUTLET

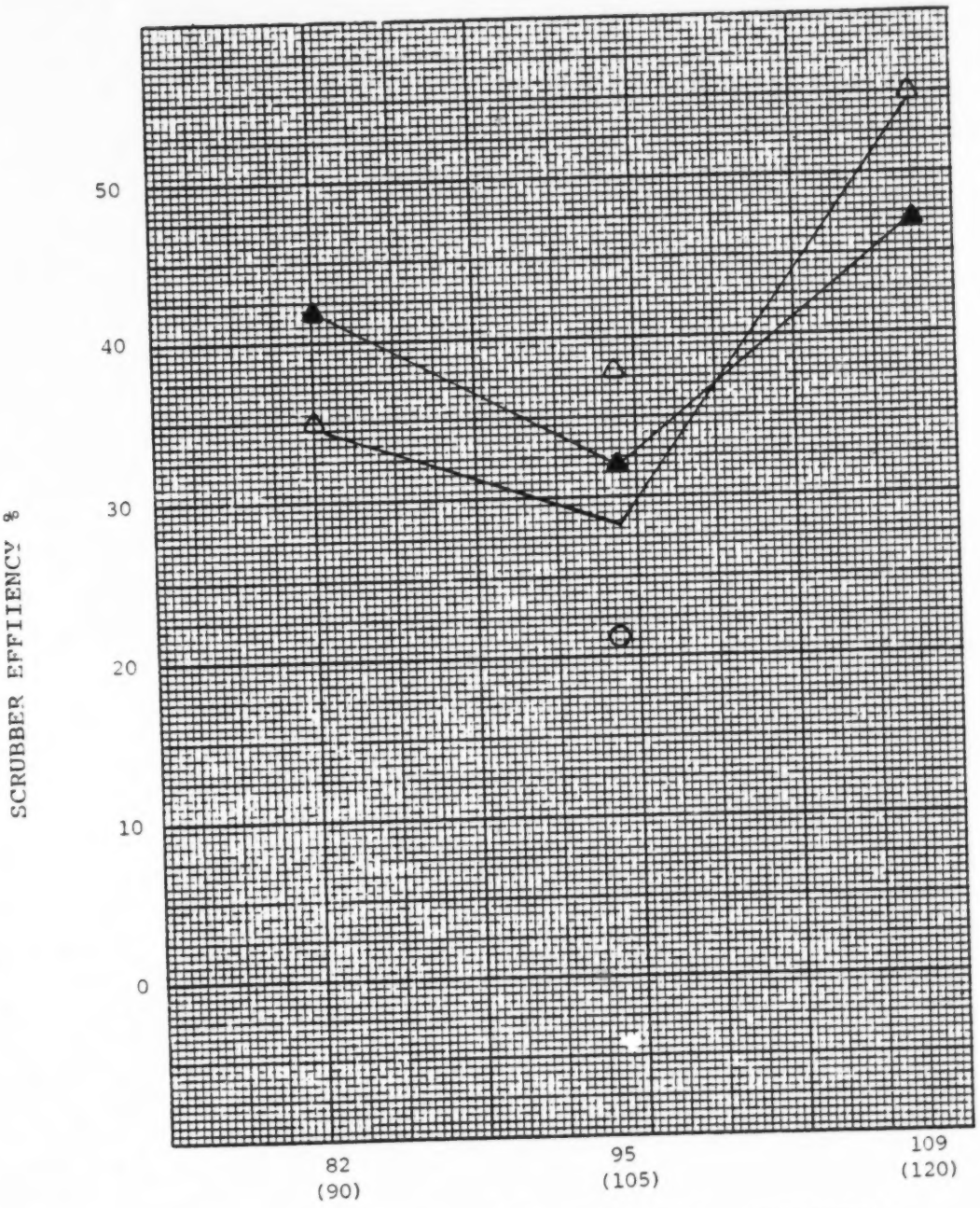


LEGEND

○ AVE. YRC @ 271°C, (520°)
△ AVE. BETZ @ 271°C, (520°F)
▲ AVE. BETZ @ 288°C, (550°F)

FIGURE 10-10

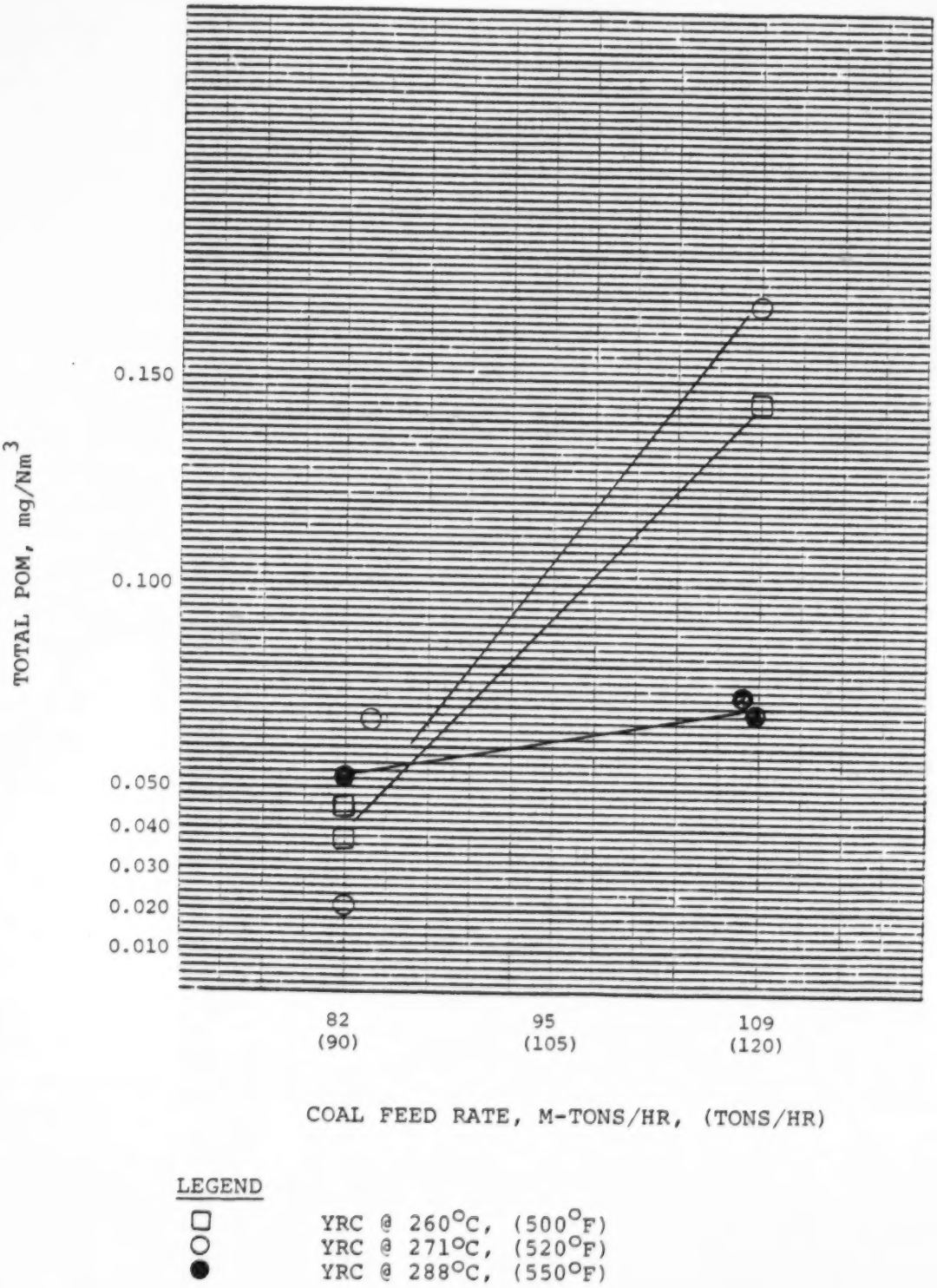
EFFECT OF COAL FEED RATE AND PREHEATER OUTLET TEMPERATURE ON CHLOROFORM SOLUABLE ORGANIC SCRUBBER EFFICIENCY



LEGEND
YRC @ 271°C (520°F)
AVE. BETZ @ 271°C (520°F)
AVE. BETZ @ 288°C (550°F)

FIGURE 10-11

EFFECT OF COAL FEED RATE AND PREHEATER OUTLET TEMPERATURE ON TOTAL POLYCYCLIC ORGANIC MATERIAL (POM) CONCENTRATION AT SCRUBBER INLET



LEGEND

□ YRC @ 260°C, (500°F)
○ YRC @ 271°C, (520°F)
● YRC @ 288°C, (550°F)

FIGURE 10-12

EFFECT OF COAL FEED RATE AND PREHEATER OUTLET TEMPERATURE ON TOTAL POLYCYCLIC ORGANIC MATERIAL (POM) CONCENTRATION AT SCRUBBER OUTLET

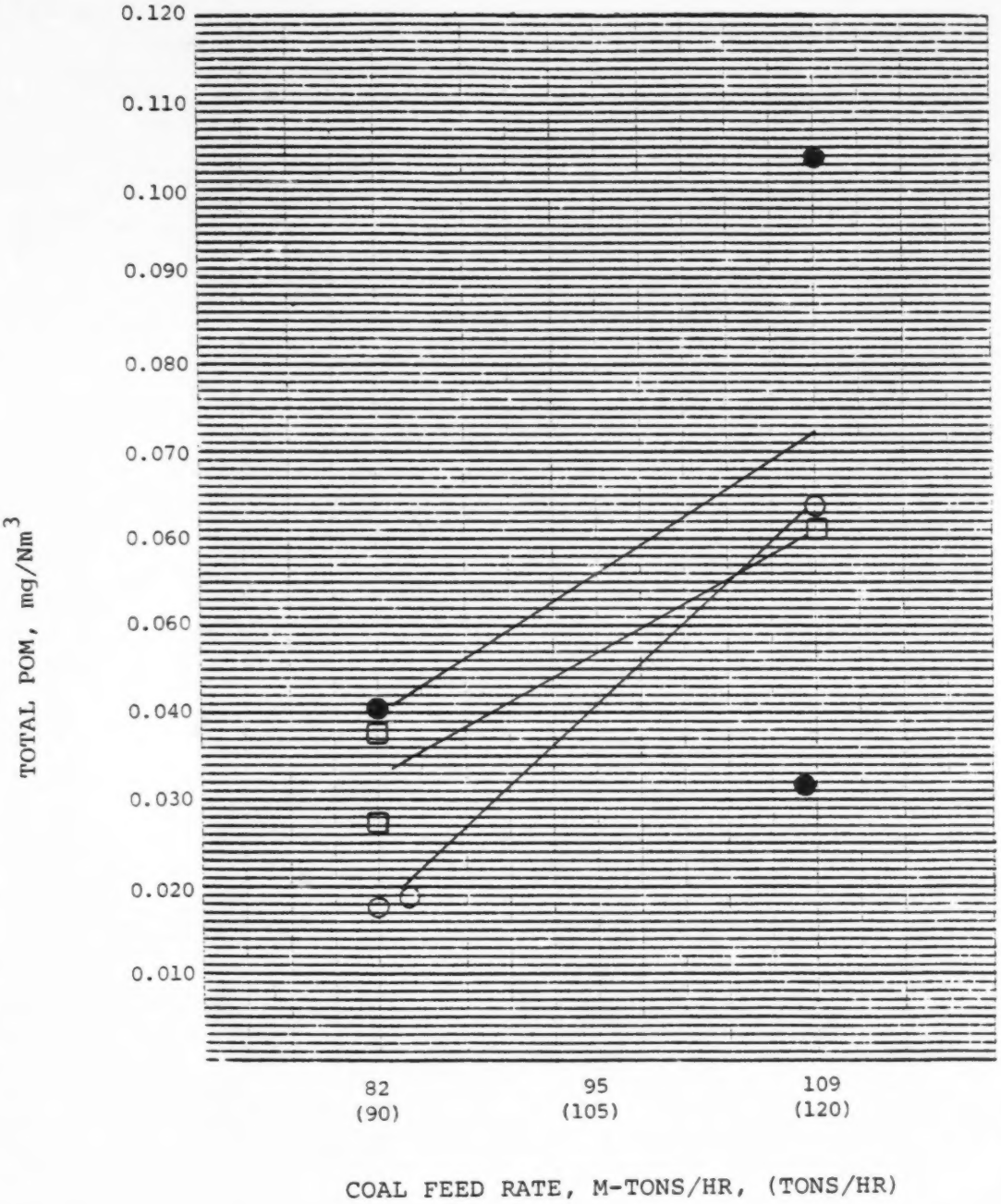
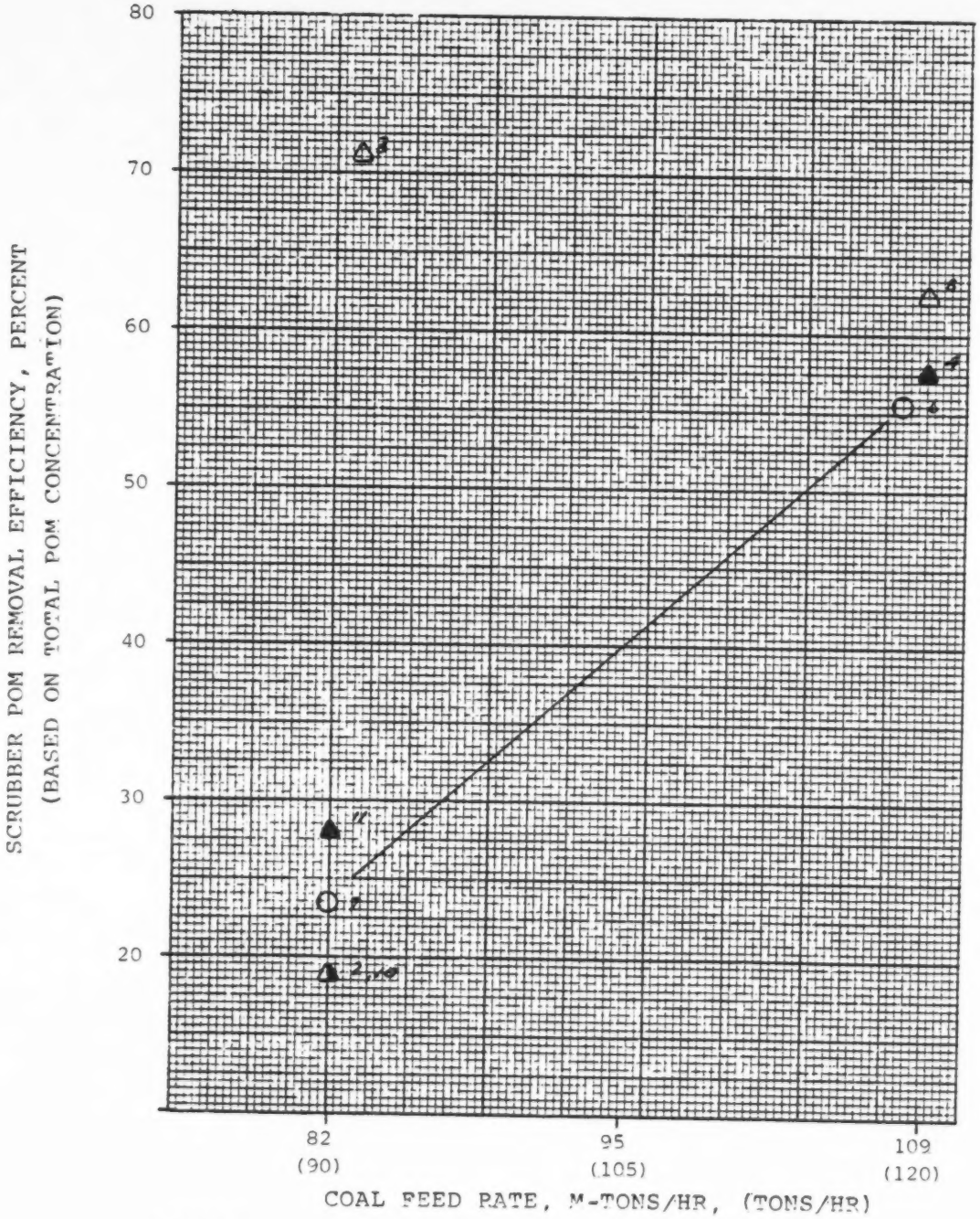


FIGURE 10-13

EFFECT OF COAL FEED RATE AND PREHEATER OUTLET TEMPERATURE ON TOTAL POM CONCENTRATION SCRUBBER EFFICIENCY



LEGEND

YRC @ 260°C
YRC @ 271°C
YRC @ 288°C

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